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LIFE:

OUTLINES OF GENERAL BIOLOGY

BY

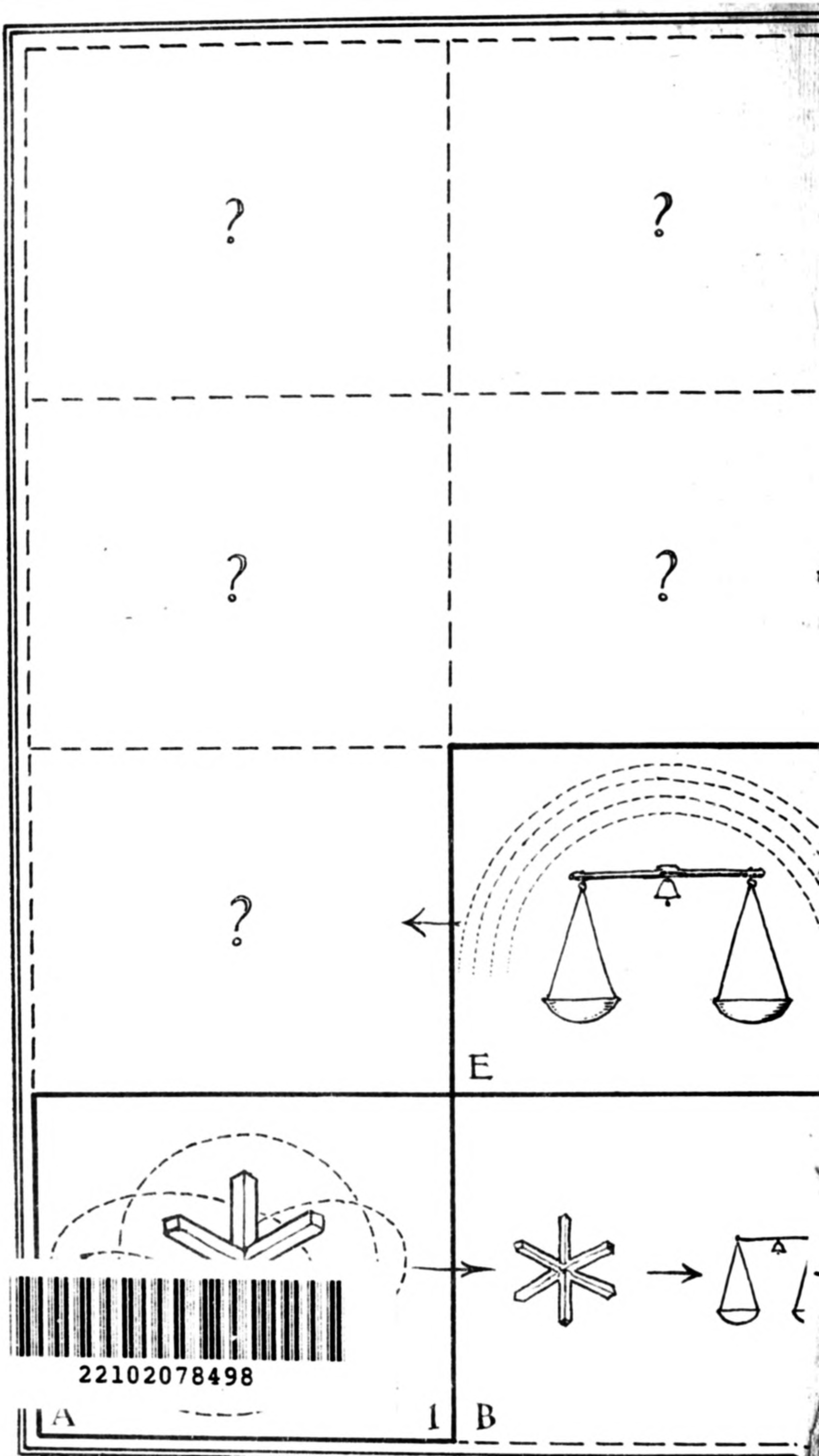
SIR J. ARTHUR THOMSON, M.A., LL.D. (Edin.; McGill; et Calif.)

Emeritus Professor of Natural History in the University of Aberdeen

AND

PATRICK GEDDES

VOLUME TWO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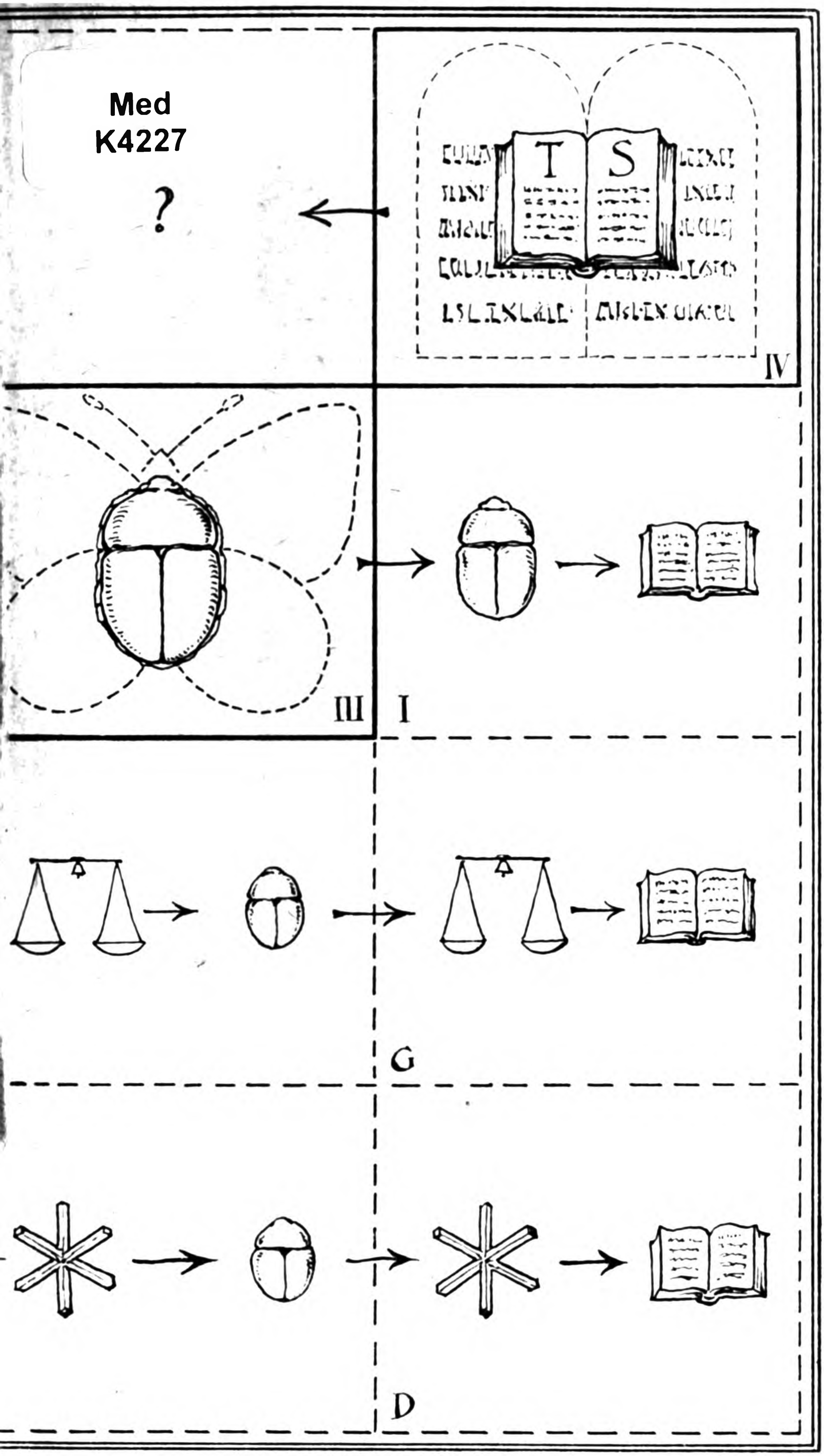
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JOINT BOOKS BY THE AUTHORS

The Evolution of Sex (Walter Scott, 1889; revised Edition 1901; out of print). In the Home University Library (Thornton Butterworth), Sex (1914); Evolution (1911); Biology (1925).

BOOKS BY PROF. GEDDES

Chapters in Modern Botany (Murray, 1893); City Development (Edinburgh, 1905); Cities in Evolution (Williams & Norgate, 1914); An Indian Pioneer of Science: The Life and Work of Sir J. C. Bose (Longmans, Green & Co., 1917); Reports on Town-Planning in India; City Development: Dunfermline (Carnegie Trust, 1904); Town-Planning towards City Development (Indore, 1918, and Batsford, London), and other Reports on Cities; Making of the Future Series (Williams & Norgate and Leplay House Press) including Ideas at War (with Dr. Gilbert Slater, 1917), Our Social Inheritance (with Victor Branford, 1919), The Coming Policy (with Victor Branford, 1917).

BOOKS BY PROF. THOMSON

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The Study of Animal Life (Murray, 4th Edition, 1917); The Science of Life (Blackie, 1899); The System of Animate Nature (Williams & Norgate, 1920); Introduction to Science (Home University Library, Thornton Butterworth, 2nd Edition, 1928); Outlines of Zoology (Oxford University Press, 8th Edition, 1929);

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CHAPTER VII

THE DEVELOPMENT OF ORGANISMS

(Embryological)

INTRODUCTORY.—From the strange evolutionary history of words, it is here well to recall that *evolutio* was first used to express a theory no evolutionist now in that sense holds, a quaint sort of germ-theory inverted, of the unfolding of the egg, regarded as an already formed miniature of the adult. To meet criticism it was added that the pre-formed miniature must contain in its germ an ultra-miniature, and so on; like a nest of Chinese boxes being unpacked since the creation. Modern embryology, since Harvey, has on the contrary been following up what he called *epigenesis*, the process which Von Baer, its modern re-initiator, formulated in the law on which Herbert Spencer so largely built his philosophy, that "the progress of development goes from the general to the special". But beyond this conception, now so concretely verified throughout living Nature, further general ideas have long since arisen; as notably "the biogenetic law" which Haeckel so especially emphasised, and so boldly applied, that ontogeny repeats the course of phylogeny, i.e. that the phases of development of the individual are essentially recapitulations of the history of its race. Hence Haeckel's Gastræa theory, for him a central clue throughout long-ascending series: or again his emphasis on the Nauplius larva as ancestral for the protean crustaceans, or again his comparisons of similar embryos throughout the Vertebrate series from fish to man. There was much truth in all this; a tadpole does in some measure represent a gill-breathing and fishy ancestor, and then a lunged fish, till it has lungs alone. But his sketchings were too bold; hence a reaction followed, to embryological work in far more accurate detail, and with many corrections of his outlines accordingly. Still, it is now only fair to him to recall that he had so far anticipated these: for beside his basal recapitulatory principle of "palingenesis", and its frequent abbreviation in many forms towards more and more direct development, he was, of course, not blind to the extraordinary modification of larval and yet more of pupal life in insects, for the latter phase especially cannot be imagined as an ancestral one. The vast bulk of evidence points to the now so frequent larval stage as an acquired byway, in course of ascent from primitive insects with no metamorphoses at all. Kindred phenomena appear in not a few other developments; so while Haeckel went too fast

and far, even his most visionary simplifications had in them the suggestive values of vision.

His essential theorising has indeed been yet more boldly applied to the interpretation of racial evolution, as notably by the American palæontologists, from Hyatt onwards. Viewing the course of individual life as not only from embryonic to adolescent and adult phases, but beyond this to senescence and death, they have applied this in careful detail to the history of species, genera, and families, as notably through the rich series of well-preserved shells of cephalopods and other molluscs. They have first traced out the series, from straight belemnites, through bent and curved forms, to loose-coiled and thence to close-coiled forms like Nautilus; and they have shown that this evolutionary series is corroborated in the actual development of some fossils. They next trace a similar series amongst fossil Ammonites, which go farther in their complications, such as the partitions so remarkably developed between successive chambers. They interpret these, and also the external elaborations of shell-markings, etc., as indications not only as so far in progressive series, but next as reaching to exaggeration beyond utility; and all this they associate with the decline and approaching extinction of the species, no less than with that of the individual. In other forms, again, they find regressions in shell-forms after the acme of their progress, and towards simplification of coiling and other complexities; and this they interpret as senescence carried on into senilescence, and thus towards extinction of the race as well as the individual death. It is a speculation familiar as far back as our biologic memories go, that the great Irish deer, with his vast spread of antlers, exaggerated in weight even beyond the strength of the big skeleton, died out from over-specialisation; and so for the sabre-toothed tiger, whose immense canines seem to have outgrown their purpose; and again for various elephantine types, surely over-tusked, to magnificent uselessness. Such views, then, are well worth considering, and they seem to be gaining ground: thus one of our most experienced palæontologists, Smith Woodward, interprets the giantism in which so many groups have culminated, like so many reptiles of the past, or whales and elephants to-day, as a sign of their approaching decline; but here surely for obvious reasons, as of great consumption of food threatening to pass beyond supplies, of slower maturity and of lessened rate of reproduction rather than from senescence proper. A more distinctly senescent character seems that of the thickened and spiny shells of many molluscs, the stony armour of many crabs as compared with lobsters, or the exaggeration of coat-armour in so many extinct fishes, reptiles, and more.

Degeneracy, too, has often been associated with specific and individual senescence. Yet loss of teeth, as by birds, has been turned to varied evolutionary purpose. And among mammals, the toothless

Echidna, Ornithorhynchus, and ant-eater have lasted well so far; thanks doubtless to fresh adaptations, so obvious indeed in the last named of these.

But our point here is that in an approach to the general fact of individual development, it is important to keep in mind its relation to racial evolution, of which it is in some measure a condensed recapitulation, especially as regards the great steps in organ-forming.

THE EGG-CELL OR OVUM.—In some animals, as we have noticed in a previous chapter, there is asexual multiplication by buds or by separated-off pieces of the body; occasionally parthenogenesis occurs, in which the offspring has a mother but no father; but with these exceptions every multicellular animal begins its

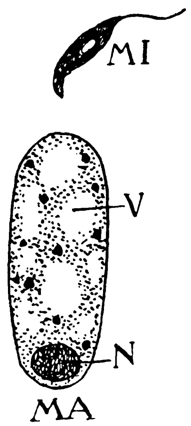


FIG. 107.

Dimorphism of Sex-Cells. MA, a macrogamete, comparable to an egg-cell, showing the nucleus (N) and vacuoles (V). MI, a microgamete, comparable to a sperm-cell.

life as an egg-cell with which a male cell or spermatozoon has entered into intimate union in fertilisation.

The ovum has the usual characteristics of a cell; its cytoplasm is a complex colloidal mixture of substances; its nucleus or "germinal vesicle" contains a definite number of rodlets or loops or otherwise shaped bodies (chromosomes) which carry the "genes" or hereditary initiatives; there may be distinct inclusions (e.g. mitochondria) in the cytoplasm; there is often a store of reserve material or yolk, and this may be relatively large in amount; and round the whole there is a delicate cell-membrane representing a cell-wall, often added to extrinsically so that it becomes a multicellular envelope, and often protected inside a non-living shell, familiarly calcareous in birds, chitinous in insects, and horny in skates and dogfish.

The size of the ovum varies enormously in different types, but the differences are more due to the amount of yolk than to the

amount of living matter. The egg of the frog is $\frac{1}{10}$ inch in diameter, and that is counted as large; for in many mammals $\frac{1}{100}$ inch is a common size, and the lancelet's is $\frac{1}{250}$ inch. Yet a shark's egg-cell, hugely bloated with yolk, may be as large as an orange, and the largest cell in the world is the "yolk" of an ostrich's egg, on the top of which there lies a nucleated drop of living matter, the essential part of the extraordinarily inflated cell. Even a small egg-cell, say $\frac{1}{10}$ of a pin's head, may be a thousand times larger than a sperm-cell; indeed, a thousand spermatozoa may be rushing round in the investing semi-fluid film. In some cases the sperm-cell is $\frac{1}{100000}$ times the size of the egg-cell. Yet the more important fact is that the ripe egg-cell and the ripe sperm-cell contain in their nuclei the

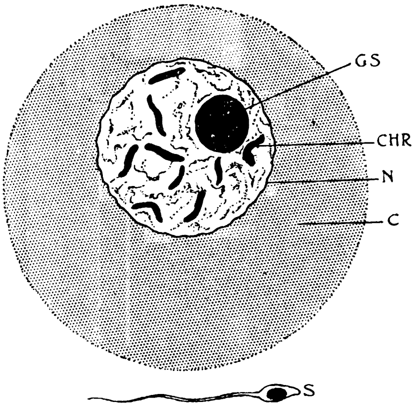


FIG. 108.

A Spermatozoon (S), showing the head with the nucleus and the locomotor tail. In proportionate magnification, a typical ovum: C, cytoplasm; N, nucleus; CHR, chromosome; GS, germinal spot or nucleolus. A sperm may be 1/100,000 the size of an egg-cell the size of a small pin's head.

same number of chromosomes. The egg-cell has more building material, but not more inheritance.

The colloidal cytoplasm of the egg is not always homogeneous, but shows some visible localisation. There are areas differing in concentration and in rate of metabolism, and these are sometimes marked by difference of colour in the living egg-cell, as in some Tunicates. But while these may be normally concerned with supplying building material for certain organs of the prospective body, they are not separable in a hard and fast way. They are not defined like the patches on a harlequin's coat. There appear to be delicate films vaguely separating different regions of the cytoplasm, but the detailed reticular or fibrillar or other microscopic structure that can be seen in fixed and stained egg-cells is believed to be due to post-mortem changes. By using different methods it is possible to see different detailed structure in the same kind of egg, which indicates clearly that the nets and fibrils and so forth are artefacts,

The young ovum is sometimes slightly amœboid; and occasionally, as in Hydra, there is an exaggeration of this feature. In the fresh-water Hydra, as in the simple marine hydroid Tubularia and some other cases, the young ovum engulfs the adjacent cells in the ovary, so that there is a very drastic struggle for existence at the very threshold of life. In the case of Hydra, a single ripe ovum is the only vigorous cell left in the minute ovary. But in most cases the nutritive material is obtained more passively, e.g. from special yolk-glands, as in Flat Worms, or from the vascular fluid of the body, as in birds and reptiles. The yolk often consists of a mixture of fatty substances, like lecithin, and protein substances, like vitellin. Since the yolk, whether large or small in amount, is intracellular and surrounded by the cell-membrane or vitelline membrane, it must not be confused with the more external "white of egg" which is often present. This albumen, familiar in the eggs of birds and in the jelly of frog's spawn, is partly nutritive and partly protective. It is usually a proteinaceous secretion of the wall of the oviduct.

Of some importance is the amount and disposition of the yolk within the egg, for this largely determines the way in which the fertilised egg-cell will divide. (*a*) The yolk may be small in amount and distributed uniformly, as in the ova of ordinary mammals, earthworms, starfishes, and sponges. In such cases the segmentation is total (holoblastic) and equal. (*b*) Or the yolk may be more abundant and sinks to the lower hemisphere of the ovum, being heavier than the living matter. This is well seen in the amphibian egg, and it also occurs in some sponges, some Cœlentera, worms, and molluscs, in the lamprey, and in Ganoid and Dipnoan fishes. There is not enough of yolk to hinder complete segmentation, but the cells are unequal, the upper hemisphere showing more numerous smaller cells, the lower hemisphere showing fewer, larger, yolk-laden cells. This is called holoblastic unequal segmentation. (*c*) A third arrangement is seen in many crustaceans and insects, but not outside the Arthropod phylum. There is a considerable quantity of yolk, which accumulates in the core of the spherical or oval egg-cell, and is entirely surrounded by the formative protoplasm. This results in partial (or meroblastic) and peripheral segmentation, the nutritive core remaining undivided. (*d*) Fourthly, there may be a relatively large quantity of yolk on the top of which the formative protoplasm lies as a small polar disc, like a watch-glass turned upside down. Only the polar area divides, forming a disc of cells or blastoderm. The mass of (telolecithal) yolk is purely nutritive, feeding the embryo, but not forming any of it. This is the partial discoidal type of segmentation, and it occurs in all Cephalopods, all cartilaginous and Teleostean fishes, all reptiles and birds, and also in the two lowest mammals—the oviparous Monotremes, the duck-mole and the Spiny Ant-eater. We shall return to the segmentation

of the egg, but in the meantime it is important to recognise that its general type depends on the quantity and the disposition of the yolk.

The envelopes or investing sheaths of the ovum are of various kinds: (1) made by the ovum itself and of the nature of a cell-wall, the delicate vitelline membrane, which is always present; (2) formed by adjacent cells, sometimes sister-cells of the ovum, as in many insects, and sometimes arising from the connective tissue of the ovary, the result being a follicular envelope, as in Tunicates, or a firm multicellular vitelline capsule, as in birds; and (3) the product of special glands or groups of glandular cells in the walls of the oviduct, the result being some kind of shell. In the middle of the oviduct of the skate there is a large "oviductal gland" which secretes through many pores a liquid gluey horn or keratin. This coalesces into a firm shell, "the mermaid's purse", filled with white of egg, and the large ovum floats in the middle. In dogfishes the four corners of the purse form very long tendrils, remaining short in skate's eggs, which twine automatically round and round seaweeds or zoophytes. Thus the egg-case is saved from being smothered in the mud, and its passive movements, as it sways about, may facilitate the aëration of the embryo. When the young fish is well formed and is coming to an end of the nutritive resources in its yolk-sac, a chemical change occurs in the albumen and a slit is formed at one end of the purse, out of which the creature forces its way. Firm sheaths, like these mermaid's purses and the calcareous shells of many reptiles and all birds, must be formed after fertilisation, for no sperms could get through the shell. Yet this must not be regarded as too obvious, since many of the eggs of insects are surrounded before fertilisation by firm chitinous shells, through which no sperm could penetrate. In these cases we find on the chitinous shell a minute aperture or micropyle through which a spermatozoon may enter. Often there are several micropyles, and as the spermatozoa sometimes move round and round the shell in varying orbits, one of them is likely to find an entrance. When the fertilisation is in this way effected, a change in the egg-cell may block the openings; but cases are recorded where several sperms effect entrance into the insect's egg. Egg-shells in the strict sense are, of course, to be distinguished from egg-capsules or cocoons, in which several eggs are wrapped up together. Thus the cocoon of an earthworm contains numerous ova, though it is but rarely that more than one of these succeeds in developing into a miniature worm. Good examples of capsules are the small vases made by the dog-whelk, and here again there is a struggle for existence in the cradle.

SPERMATOZOON OR MALE CELL.—In typical cases the spermatozoon is very minute and very active. In its minute size,

locomotor energy, and persistent vitality, it resembles a flagellate Monad, whereas an ovum is comparable to a hungry Amœba or to one of the more encysted Protozoa, such as a Gregarine.

A typical spermatozoon shows (1) a "head", mostly made up of the nucleus with its chromosomes, and sometimes capped by a minute "acrosome" which first attaches itself to the egg-cell in fertilisation; (2) a locomotor tail, sometimes with an axial filament, a fibrillated sheath, and a delicate fringe; and (3) between head and tail, a short "middle piece", in which there is usually a "centrosome", regarded by many as important in the cleavage that follows fertilisation. The spermatozoa of threadworms and many crusta-

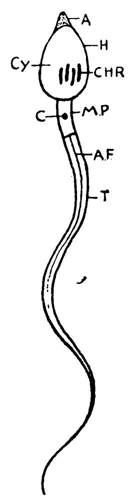


FIG. 109.

Diagram of an Animal Spermatozoon. A, the firm peak or acrosome; H, the head; Cy, the cytoplasm of the head; CHR, the nuclear chromosomes; MP, the middle piece, including the centrosome (C); AF, the axial filament of the locomotor tail (T).

ceans are sluggish and inclined to be amœboid. In the threadworms there is internal fertilisation, and the sluggish sperms meet the ova towards the lower end of the female genital duct, being apparently wafted inwards by motile tags on the internal wall. In many of the crustaceans there is internal fertilisation; in others, like the crayfish, the male may deposit the sperms on the liberated eggs which are attached to some of the appendages of the female. It has often been pointed out that the fixed barnacles have mobile spermatozoa, and it is plain that the occurrence of sluggish sperms would be a severe handicap to sedentary types. But as a matter of fact there are other crustaceans besides barnacles that have mobile sperms, such as many Ostracods and the water-flea Polyphemus.

Sometimes, as among Crustaceans, there are adaptations which secure fertilisation when the sperms are non-mobile; thus many

may be enclosed in a packet or spermatophore, which breaks up after being deposited among the eggs; while others, as in some of the highest members of the class, have complex explosive spermatozoa which burst violently when their outstanding processes touch and adhere to an egg, the result being that the nucleus and a centrosome are forced through the egg-membrane. In Ostracods the sperms do not become mobile until they pass into the female genital duct, and in some of these water-fleas the spermatozoa

FIG. 110.

A Spermatozoon of a Newt. After Ballowitz. 1, apical spur; 2, nucleus, composing most of the head; 3, tail with vibratile fringe (4), and end piece (5).

are gigantic, even $\frac{5}{6}$ inch in length, three or four times longer than the whole tiny animal! We need give no further illustrations of variety among spermatozoa.

SPERMATOGENESIS AND OÖGENESIS.—In sponges the germ-cells arise in the middle stratum or mesoglœa of the body, which has not yet acquired organs of any kind. In Cœlentera the germ-cells arise in connection with either the inner or the outer layer (ectoderm or endoderm), and in some cases there are well-defined reproductive organs or gonads, such as are conspicuous in the common jellyfish, Aurelia, which swims in all the seven seas. In other animals the

reproductive organs arise in connection with the middle layer or mesoderm, and usually on an area of epithelium lining the cœlom or body cavity. The general fact is important, that the gonads arise from patches of unspecialised germinal cells, which have not shared in building up the body of the parent, and have retained the

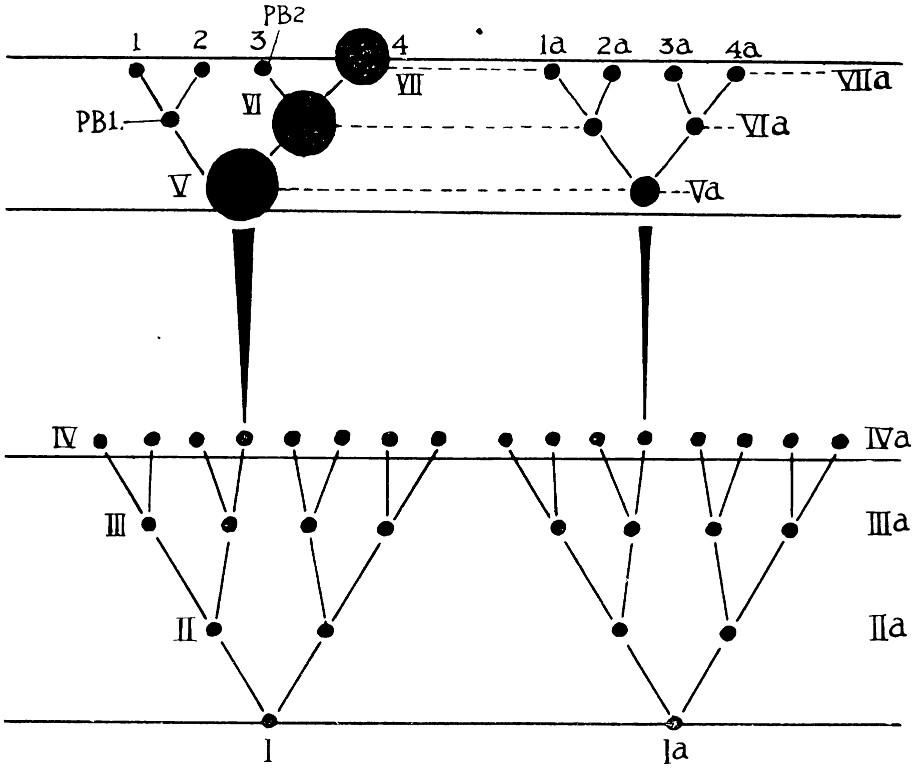


FIG. 111.

Oögenesis (to left) and Spermatogenesis (to right). After Boveri. I, Primary oögonium; II–IV, its multiplication into oöcytes. Ia, Primary mother-sperm-cell; IIa–IVa, its multiplication into spermatogonia and spermatocytes. V, A ripe oocyte gives off, by meiotic division, the first polar body (PB1), which may divide mitotically. VI, The reduced ovum gives off, by mitotic division, the second polar body (PB2), and becomes the matured egg-cell (VII) or 4. Va, A spermatocyte divides meiotically into two spermatocytes (VIa) with the haploid number of chromosomes; and these divide mitotically into spermatocytes which become ripe spermatozoa. Note the theoretical presence of four cells (1–4; 1a–4a) at the end of each lineage.

whole inheritance intact in the nuclei of their undifferentiated cells. In other words, the germ-cells in the gonads belong to a lineage of undifferentiated cells, unlike the somatic cells which exhibit division of labour as muscular, nervous, glandular, skeletal, and so forth. It is said that (unspecialised) somatic cells in the frog may give rise to germ-cells, but, if this is the case, it is very unusual. Another general fact of importance is that the early stages of ovaries and

testes are so like one another that it is difficult for a time to distinguish the young male from the young female.

Ova and spermatozoa are true cells, complementary to one another in fertilisation, but the spermatozoon has a longer cellular lineage behind it, and the real homologue of the ovum is the spermatogonium or sperm-mother-cell in the testis. These spermatogonia, sometimes not unlike very young ova, divide and redivide into smaller spermatocytes. There is often an interesting resemblance between the ways in which spermatogonia divide and the modes of segmentation in ova; thus a sperm-morula is not unlike an ovum with partial peripheral segmentation. But it is unlikely that this resemblance means more than that the ways in which a cell can divide are few. There may be several generations of spermatocytes, and eventually spermatids are formed, which then turn into special-

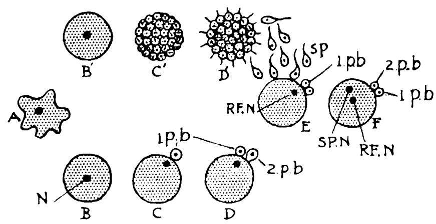


FIG. 112.

A, Primary Germ-Cell, amœboid; B′, a spermatogonium, which divides into a sperm-morula (C′ and D′), giving rise to separate spermatozoa (*sp*); B, an unripe egg-cell or oocyte; C, the egg-cell giving off the first polar body (1*pb*); D, the formation of the second polar body (2*pb*); E, the egg-cell with reduced female pronucleus (RFN); F, fertilisation, the intimate orderly union of the two reduced sex-nuclei, namely the sperm nucleus (SPN) and the reduced female pronucleus (RFN).

ised spermatozoa. But at some stage in the spermatogenesis, there is a reduction or meiotic division, and this often occurs at the formation of the second last crop of spermatocytes. We shall return to this meiosis in connection with the ovum, in whose maturation a similar process occurs, but the large fact is that the normal number (n) of chromosomes is halved, so that in the last crop of spermatocytes there is in each cell half that number $\left(\frac{n}{2}\right)$. If the spermatocytes with the reduced or haploid number of chromosomes should divide again, they divide in the ordinary equational or mitotic fashion, so that the spermatozoa have still the $\frac{n}{2}$ number. In the many diverse types there are differences in the details of spermatogenetic reduction, and as regards the stage at which it occurs; but in most cases

a spermatocyte of the penultimate set divides into two spermatocytes with $\frac{n}{2}$ chromosomes, and each of these divides mitotically into two spermatids or young spermatozoa, each with $\frac{n}{2}$ chromosomes. Thus each penultimate spermatocyte gives rise to four germ-cells, all viable, each with the reduced number of chromosomes. Here the parallelism with the reduction in ovum maturation is very close, as will be seen; but in the case of the ovum, only one of the four final cells, the ripe ovum itself, is viable.

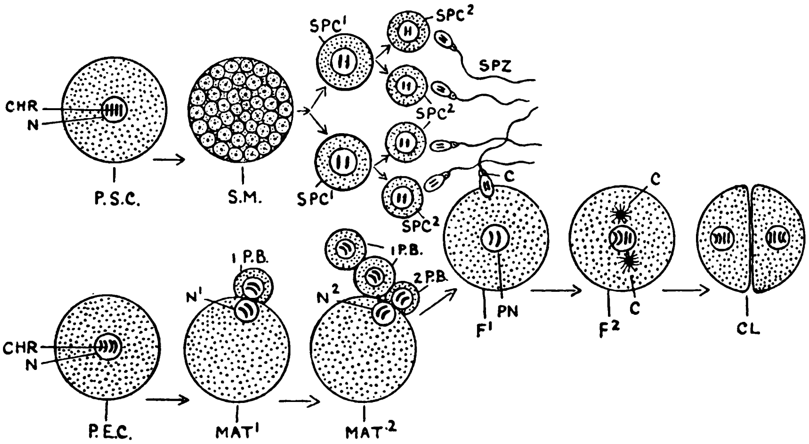


FIG. 113.

Comparison of Sperm-Development and Ovum-Development. P.S.C., primitive sperm-cell; with nucleus (N) and its chromosomes (CHR); SM, sperm-morula, giving rise to spermatocytes which again divide (SPC^1 and SPC^2). In the penultimate spermatocytic division meiosis occurs, and the number of chromosomes is reduced to a half. The final spermatocytes develop into spermatozoa (SPZ). PEC, primary egg-cell, with its nucleus and chromosomes; MAT^1, the extrusion of the first polar body (1PB), effecting meiosis; MAT^2, the extrusion of the second polar body (2PB) by mitosis. The first polar body may divide into two. F1, fertilisation of mature ovum, with its reduced female pronucleus (PN), by the entrant spermatozoon with its centrosome (C); F^2, fertilised ovum with the normal number of chromosomes restored; CL, cleavage or first division of the fertilised ovum.

MATURATION OF OVUM.—Primordial germ-cells or oögonia in the ovary multiply by mitotic division and form many oöcytes. After a period of multiplication, there is a period of growth, and the oöcytes become larger. They may burst from the ovary at this stage, but they have still to go through the process of maturation. The nucleus of the unripe ovum moves to the periphery and divides meiotically into two, giving off the first polar body, which thus contains $\frac{n}{2}$ chromosomes. The first polar body, though a sister-cell of the ovum, never comes to anything, but it may divide equa-

torially into two. Meanwhile the reduced nucleus of the egg-cell, without the resting phase which usually follows a division, gives off equatorially another polar body, usually called the second polar body. Thus the oöcyte with n chromosomes has given rise to four cells with $\frac{n}{2}$ chromosomes: (1–2) the first polar body and its neighbour if it divides, (3) the second polar body, and (4) the ripe ovum whose reduced nucleus retires from the periphery to the centre, and is known as the female pronucleus. The ripe ovum is the only viable cell of the four—a contrast to what occurs in spermatogenesis.

The typical history of an ovum includes the extrusion of polar bodies and the associated reduction of the chromosomes to half the normal number, but there is exceptional behaviour in parthenogenesis. In some parthenogenetic ova, only one polar body is formed,

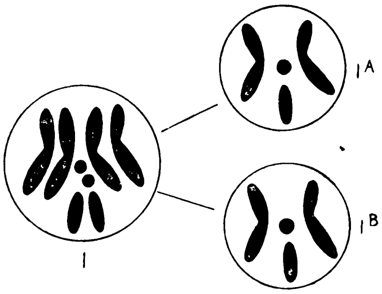


FIG. 114.

Reducing or Meiotic Division. The diploid number of eight chromosomes in cell 1, is reduced to the haploid number of four chromosomes in each of the cells 1A and 1B.

and there is no reduction in the number of chromosomes. In some other cases the parthenogenetic ovum exhibits the usual reduction division and forms two polar bodies. But the second of these is not set adrift; it remains within the ovum and reunites with the reduced nucleus, thus restoring the normal number of chromosomes. In ordinary cases the large fact is that the ripe ovum and the ripe spermatozoon contain, as the result of meiosis, the haploid or $\frac{n}{2}$ number of chromosomes.

REDUCING OR MEIOTIC DIVISION.—If it were not for the reducing division during maturation, the number of chromosomes would be doubled at each fertilisation, which is absurd. But the reducing division has a deep biological significance of its own, and this makes it desirable to go into some detail as to what occurs. It may be enough, however, to keep to what happens in a large number of cases.

The n chromosomes in an immature germ-cell occur in pairs, one member of each pair being of paternal origin and the other of maternal origin. The two members of each chromosome pair come into intimate physical contact, one often lying in a line with the other, like two rodlets end to end. Then one of the two swings round so that they lie one above the other, so closely apposed that the total number appears $\frac{n}{2}$. The physical contact of the two homologous chromosomes is called synapsis, and it may involve interactions of moment. Thus, as we shall afterwards notice, a segment of the one chromosome may exchange places with a segment of the other ("crossing over"). In each of the $\frac{n}{2}$ double chromosomes there is a median separation of the one from the other, so that rings or double **V**'s are formed, and these arrange themselves at right angles to

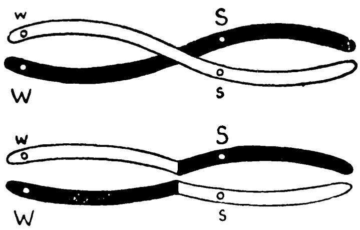


FIG. 115.

The Crossing Over Process in Two Chromosomes of a "Synaptic Pair". Part of the chromosome coloured white interchanges with part of the chromosome coloured black.

the equatorial plane of division. If we suppose n to be 8, there are four half-rings, with their broken ends touching, or four **V**'s with the apices of each limb touching. What happens then is that division occurs, taking off four half-rings or four **V**'s, and leaving the $\frac{n}{2}$ number. Thus if the normal number of chromosomes in an unripe egg be 8, the first polar body takes off 4 and leaves 4.

If the homologous chromosomes, paternal and maternal in origin, always lay in the same relation to one another in forming rings or appôsed **V**'s—if, for instance, the paternal chromosomes were always towards the periphery of the ovum—then the formation of the first polar body would remove all the paternal chromosomes. But it appears to be quite fortuitous whether the first polaody gets two paternal and two maternal chromosomes, or three and one, or one and three—on the supposition that 8 is the normal number. Now there is good reason to believe that each of the chromosomes of a homologous pair carries the same complement of similar genes

(or hereditary factors, or developmental initiatives), the maternal and paternal contributions being *as regards essentials* duplicates. But if in a paternal chromosome there was a peculiar gene, a novel Mendelian difference, which might be the initiative of musical genius or of red hair, there is an obvious chance that it might be lost in the first polar body. And if the spermatozoon did not happen to bring in that particular gene from the male (we are now passing to a new paternal contribution, not of the father, but of the mate), then the peculiarity in question would be lost from the inheritance for the time being .And the same would be true of a minus feature, such as some pathological taint.

As the facts are intricate, let us repeat ourselves in reference to a maternal chromosome in the unripe egg. It contains the genes of a group of hereditary initiatives which are characteristic of the species, but it may also contain a peculiarity that was expressed in the mother of the organism whose germ-cells we are discussing. The peculiarity might be unusual fecundity or it might be crinkly hair; and its gene might be lost in the first polar body. Yet it might be re-introduced into the fertilised ovum by a spermatozoon coming from a mate in whom the gene for fecundity or for crinkly hair was carried by all or by half of the final spermatocytes. Moreover, a particular novel gene in one of the chromosomes of the reduced female pronucleus may be supplemented by a similar novel gene carried by the fertilising spermatozoon. This would be what the Mendelians call a "double dose" of that particular quality; and when the quality is on the minus side the "double dose" may have serious consequences. Yet it must be remembered that in most cases there are many ova and many spermatozoa, differing in the details of their maturation. This is part of the reason for the familiar *specific inertia*—the persistent begetting of like by like.

The biological significance of the maturation division is partly that in the meiosis a chromosome separated off may carry away a gene that is not restored in fertilisation. This tends to variability, and it enables us to understand Mendelian inheritance. Moreover, in the intimate contact of a pair of chromosomes in synapsis there may be an exchange of pieces of the two chromosomes. A portion of chromosome A may slip over into chromosome A′, and vice versa. This "crossing over", as it is called, is another possibility in the shuffling of the hereditary cards; and it makes for variation.

In ordinary mitotic division, which has been previously described, each chromosome is longitudinally split down the middle, and each daughter-cell receives a meticulously accurate half of everything in the cell, including a longitudinal half of each chromosome. So the normal number n persists. In meiosis, as has been explained, the number of chromosomes is halved. Those who are unfamiliar with this important difference between mitotic and meiotic division, the

latter restricted to the maturation of the germ-cells, may think of two ways of dividing a boxful of wooden matches. One might with a penknife split each of the two dozen matches up the middle, and put two dozen halves into a new box. That would correspond to mitotic division. Or one might put a dozen of the matches into a new box, and that would correspond to meiotic division. This is the gist of the contrast, though there are other differences, such as the fact that the double-chromosomes arrange themselves in meiotic division at right angles to the equatorial plane, whereas they lie in the plane of the equator in mitotic division.

FERTILISATION.—In the seventeenth and eighteenth centuries it was believed by some naturalists, nicknamed "ovists", that the ovum was all-important, only needing the sperm's awakening touch to begin unfolding the miniature model which it was supposed to contain. Others, called "animalculists", were equally certain that the sperm was the essential element, though it required to be fed by the ovum. It was but slowly that it became clear that the two kinds of germ-cells are complementary, but even then many naturalists thought that actual contact was unnecessary, since fertilisation might be effected by an *aura seminalis*! Though spermatozoa were distinctly seen by Leeuwenhoek and Hamm in 1679, their actual union with ova was not observed till 1843, when Martin Barry detected it in the rabbit. A knowledge of the details of the intimate and orderly union is much more recent.

Among the many facts now known in regard to fertilisation, the following are most important:

(1) In its maturation the ovum makes an attempt at independent activity, which succeeds in cases of parthenogenesis. Usually, however, the ovum sinks into static equilibrium—paralysed, according to some cytologists, by its own waste-products. It cannot be activated except by the entrance of a spermatozoon, or by the stimuli utilised in bringing about artificial parthenogenesis. The reduced female pronucleus has often passed to the centre of the ovum, and the nucleus of the spermatozoon has to make a journey through the cytoplasm to find it, attracted by some influence from a distance which, though not understood, is called chemotaxis. In many cases, such as starfishes, Annelid worms, and mammals, the spermatozoon seems to be able to enter the ovum at any point; or it may be restricted to a micropyle, or to a particular region with little yolk. In some cases it is met by a hillock of protoplasm which rises from the surface of the egg-cell, indicating that there is more than mere passivity on the ovum's part. There is indeed some visible engulfing of the boring sperm. The whole process is usually over in one minute.

When entrance has been effected, the delicate vitelline membrane

may become (as in sea-urchins) detached from the surface of the ovum to form the "fertilisation membrane", the space between it and the egg being filled with a clear fluid. This is a critical moment in the fertilisation process, for there is a marked increase in the permeability of the egg-surface, so that dissolved substance may diffuse out from the cytoplasm, and also an increase in susceptibility to external changes. Very rapidly the egg-cell is reawakened; there is a great increase in the metabolism after the fertilisation has occurred—increased consumption of oxygen, increased evolution of carbon dioxide, and increased production of heat! But a chemical and physical change around the periphery of the ovum renders it non-receptive to other spermatozoa. This "blocking" of the egg is probably advantageous, for it has been observed that the entrance of several sperms (polyspermy) is apt to set up several centres of segmentation, the result being abnormality. Polyspermy is said to be frequent among insects and cartilaginous fishes, but in these cases only one of the sperms actually combines with the nucleus of the ovum; the others come to nothing.

In entering the egg-cell—it may be by an attracting hillock—the spermatozoon leaves its locomotor tail outside; but in many cases the middle piece seems to enter along with the head, and this may introduce the centrosome. This proceeds to divide into two, which play an important rôle in the segmentation of the fertilised ovum. The immature ovum has a centrosome, but for some unknown reason this disappears. It follows that the centrosome which appears after fertilisation has either been introduced by the spermatozoon, or evoked *de novo* by its influence on the protoplasm of the egg. Some cytologists hold to the older view, that the spermatozoon introduces a centrosome, which divides into two; and this is supported by the fact that in ordinary cell-divisions, centrosomes usually arise from centrosomes. But other experts maintain that the centrosome of the fertilised ovum is a new product, and this is supported by a striking experiment made by Chambers, who, in one of his masterly manipulations, cut off the whole of the entering spermatozoon behind the head, and then observed the appearance of a centrosome as usual in the fertilised ovum. It is possible that the centrosome is introduced in some types and evoked in others.

After movement through the cytoplasm of the egg, the nucleus of the spermatozoon finds the nucleus of the ovum, and the result of their union is the "segmentation-nucleus". The union is intimate and orderly, but the reduced chromosomes of the sperm do not fuse with the reduced chromosomes of the egg. They form pairs, and each member of a pair is longitudinally split in all the subsequent divisions that are involved in the development of the embryo and eventually the whole body of the offspring. In some cases, such as the water-flea Cyclops, it has been possible to follow the early

divisions of the egg-cell, and to show that each cell has half of its chromosomes of paternal origin and the other half maternal; and to this must be added the statement that the chromosomes form homologous pairs. That is to say, if there be a chromosome (A) of maternal origin that carries the genes or factors for a certain group of characters, there will be another chromosome (A^1) of paternal origin that carries the genes or factors for the same group. It follows that Huxley was right in his extraordinary prevision of 1878: "It is conceivable, and indeed probable, that every part of the adult contains molecules derived both from the male and from the female parent; and that, regarded as a mass of molecules, the entire organism may be compared to a web of which the warp is derived from the male and the woof from the female." "What has since been gained", Prof. E. B. Wilson says, "is the knowledge that this web is to be sought in the chromatic substance of the nuclei, and that the centrosome is the weaver at the loom."

To sum up, let us answer the question: *What is implied in the fertilisation of the ovum by the spermatozoon?* (1) There is a mingling of two inheritances, paternal and maternal, slightly different from one another, the one mainly carried by the chromosomes of the spermatozoon and the other mainly carried by the chromosomes of the egg-cell. To many biologists, it remains an open question whether the extra-nuclear protoplasm carries any hereditary factors; but it must be noticed here that the egg-cell furnishes in its cytoplasm a relatively large quantity of *embryonic building material,* whereas the spermatozoon has almost none.

(2) The number of chromosomes, reduced to a half by meiosis, is restored to the normal in fertilisation. In some cases the normal number is different in the two sexes; thus it is 47 in man and 48 in woman—an interesting difference referred to in the section on sex-determination. We shall simply re-emphasise the fact that the number itself is not so important as the adherence to it throughout all the cells of the body.

(3) There is an introduction of a centrosome by the middle piece of the spermatozoon, or else there is some stimulus which evokes the appearance of a new centrosome in the cytoplasm of the egg-cell.

(4) There is an excitation of the cytoplasm of the ovum, which seems to pass from the pole where the sperm enters. This may imply an exudation between the vitelline membrane and the surface of the ovum, so that the membrane is lifted off to form the fertilisation membrane. There is in most cases a "blocking" of the egg to other sperms.

(5) But fertilisation also involves a re-activation of the egg, a rearrangement of materials, a stimulus to divide; and the first cleavage plane is determined by the entrance of the spermatozoon, and by the path taken through the cytoplasm by its nucleus

and centrosome. In artificial parthenogenesis the normal spermic stimulus is replaced by some other, usually chemical or physical, and, as the resulting development is normal, it follows that the ovum-nucleus must be complete in itself, even in cases where parthenogenesis does not occur in natural conditions. In the threadworm, Rhabditis, the spermatozoon acts as a stimulus, yet degenerates without fusing with the egg-nucleus, an interesting separation of the two functions of amphimixis and stimulation. In echinoderms it has been shown that if the fertilised ovum is cut in two before the sperm-nucleus has united with the egg-nucleus, the half containing the former may divide and develop, while the half containing only the latter degenerates and dies! It is interesting to compare this case of "Merogony" (development of a part) with what happens in the Rhabditis ovum. For what develops in the former is a piece of ovum with only a sperm-nucleus, while what develops in the case of Rhabditis is an ovum with only an ovum-nucleus.

SEGMENTATION.—The pole of the ovum towards which the nucleus or the pure formative protoplasm is nearest is called the animal pole, and it is there that the polar bodies are given off. It is the region of greatest chemical activity, greatest permeability, greatest susceptibility to environmental changes; and it is electrically negative to the rest of the protoplasm. The opposite pole, where there is most yolk-material, is called the vegetative pole, and in a freely floating egg it is usually lowest, as is readily seen in a frog's egg. In the floating ova of some fishes, however, the yolk is uppermost (often showing a buoyant oil-globule), and the embryonic area is lowest.

After fertilisation, but before the division of the egg into the two first blastomeres, there may be a visible arrangement of the materials in the cytoplasm; and the cleavage may follow so regular a pattern that it is possible to say that a particular spot in the ovum will have a certain rôle in development. Some ova are more visibly mapped out than others, but the mapping out is not radically important, since a complete embryo may be developed from a portion of an ovum, or from one of the first two blastomeres. Moreover, a complete disturbance of the visible pattern of the egg by whirling in a centrifuge may not involve any abnormality in the development.

The plane of the first cleavage of the fertilised egg-cell is typically a meridian running through the two poles of the egg, and its exact situation is determined by the path of the sperm's nucleus and centrosome through the cytoplasm. In simple cases, well illustrated by the frog's egg, the first cleavage divides the egg into prospective right and left halves; the second, at right angles to the first, into prospective anterior and posterior halves. Then follows an equatorial cleavage, at right angles to the two preceding, and this divides the

developing egg into prospective dorsal and ventral halves. But there are many departures from this simple procedure. Thus when the blastomeres are unequal in size, a spiral type of cleavage may result, as in some marine worms and molluscs. There are interesting cases, especially among insects and crustaceans, where many nuclear divisions occur without there being divisions of the cytoplasm; the result is a "syncytium", but each nucleus eventually becomes the centre of a defined cell. This suggests the conclusion elsewhere

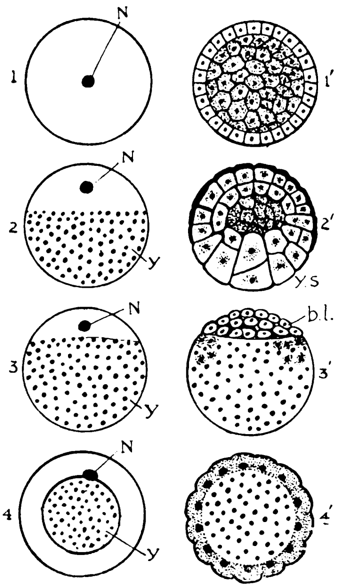


FIG. 116.

Different Modes of Segmentation shown by the Egg-Cells of Animals. 1 and 1′, an ovum with almost no yolk shows total and equal segmentation (e.g. starfish); 2 and 2′, an ovum with a considerable amount of yolk shows total and unequal segmentation (e.g. frog); 3 and 3′, an ovum with much yolk at one pole shows partial and discoidal segmentation (e.g. bird); 4 and 4′, an ovum with a central core of abundant yolk shows partial and peripheral segmentation (e.g. insect). N, nucleus; *y*, yolk; *ys*, yolk-laden cells; *bl*, blastoderm or segmented disc.

referred to that the segregation of cells is an arrangement which facilitates division of labour or differentiation.

In many cases, such as sea-urchin and frog, where the ovum is radially symmetrical to begin with, the first cleavage establishes bilateral symmetry, dividing the egg into prospective right and left halves. But the eggs of squids and of many insects have a bilateral shape and structure before fertilisation, and the axes of symmetry of the egg are the same as those of the embryo. It is evident, then, that there is considerable variety in segmentation. The four main types have been already described (see Figs. 116 and 117).

EARLY STAGES.—The result of the cleavage or segmentation of

the fertilised ovum is usually a ball of cells. But when the yolk is very abundant, as in reptiles and birds, a disc of cells—a discoidal

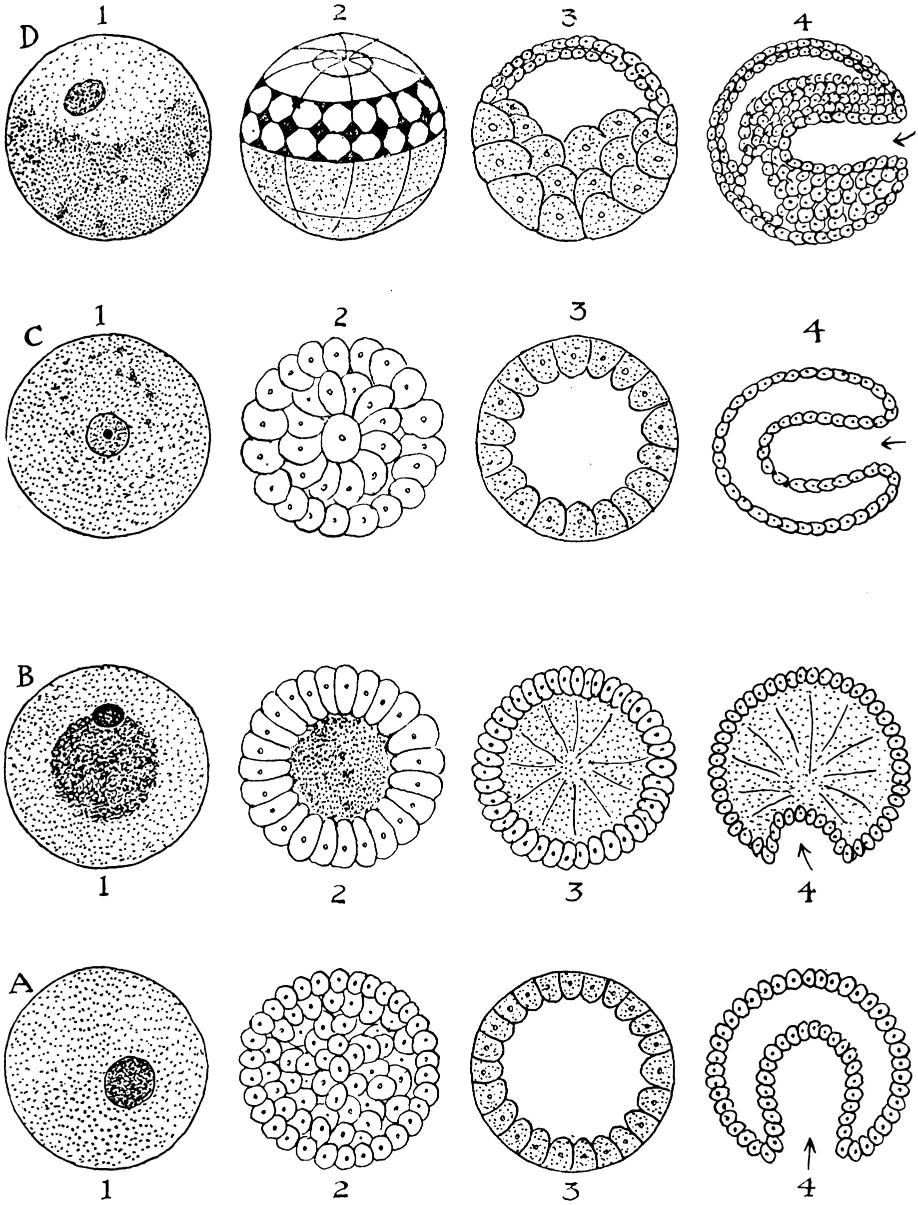


FIG. 117.

Various Types of Animal Ova (A–D), showing in (1) the undivided ovum, in (2) the segmented ovum, becoming a blastula or morula stage, in (3) a more advanced stage, in (4) the gastrulation. Thus A would represent the sequence in a starfish, B in a crustacean, C in a tunicate, and D in a frog.

blastoderm—is formed at the upper pole of the great ball of nutritive material, which it gradually surrounds.

When there is little yolk, as in sea-urchin ova, the segmentation results in a hollow ball of cells, the blastula or blastosphere, the cavity being called the segmentation cavity or blastocœl. This is a common embryonic stage and it should be understood that though it is composed of many cells, it is of the same size as the egg-cell, for the cells have not yet begun to grow. But it is lighter than the egg-cell, having used up part of its reserve material.

If the segmentation cavity is small (e.g. frog) or absent (e.g. sea-anemones), so that the ball is practically solid, the result of cleavage is called a morula. It presents an appearance like the fruit of bramble or mulberry, the external blastomeres bulging outwards. In many cases about four dozen outer cells are visible. Much must not be made of the difference between morula and blastula, for the solid ball may soon develop fluid in its interior, and a hollow ball may soon fill up its cavity with cells. Both are to be distinguished, however, from a type well illustrated by the egg of the crayfish, and restricted in its occurrence to Arthropods, where the core of the segmented egg is an undivided mass of yolk. It is highly probable that the first multicellular organisms were hollow balls of cells, such as may be seen in Volvox to-day, but it would be straining the recapitulation doctrine to maintain that the blastula of a sea-urchin or a lancelet is a recapitulation of a primitive ancestral Metazoon. After all, there are only a few different ways in which an egg-cell can divide into a coherent integrate, and the blastula illustrates one of these.

GASTRULA.—In the next chapter the cells continue multiplying, but they also begin to grow, and the result is the establishment of the germinal layers. The simplest form of this is seen in a free-swimming blastula, such as that of sea-urchin or lancelet, where the blastomeres of one hemisphere increase in number more rapidly than those of the other, with the result that the more slowly multiplying hemisphere is apparently dimpled into the other, as we might dimple an indiarubber ball which had a hole in it. Thus out of a hollow ball of cells (the blastula), a two-layered sac is formed—a gastrula. And when it arises in this way, as in coral, starfish, and lancelet, it is said to be formed by invagination or *embolé*. The mouth of the gastrula is called the blastopore, its cavity the archenteron. In all cases the archenteron becomes the digestive part of the future food-canal or enteron.

But when the ball of cells is practically a solid morula, the formation of two germinal layers must be effected in a different way. The smaller, less yolk-laden, more quickly multiplying cells, towards the "animal pole", gradually grow round the larger yolk-containing cells, and a gastrula is formed by overgrowth or *epibolé*. In these or in yet other ways the two germinal layers are estab-

lished—the outer ectoderm or epiblast, and the inner endoderm or hypoblast. It was a great step, familiar enough now, when Huxley definitely pointed out that the epiblast of an embryo corresponds with the outermost layer or ectoderm of a two-layered (diploblastic) animal, such as Hydra; and the hypoblast to the endoderm. It is now convenient and usual to abandon the synonyms epiblast and hypoblast, and keep to ectoderm and endoderm.

MESODERM.—In Sponges and Cœlentera there are only two well-defined layers, the ectoderm and the endoderm, which are separated from one another by a gelatinous material (mesoglœa) into which cells migrate. In the Ctenophore class of Cœlentera, there is for the first time a definite third layer—the mesoderm or mesoblast. Thus from this level onwards animals are called triploblastic, in contrast to the diploblastic sponges and Cœlentera.

The origin of the mesoderm is diverse and often difficult, though in the development of some types, e.g. Arrow-worm (Sagitta) and

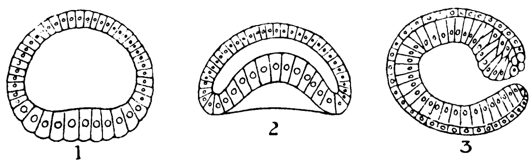


FIG. 118.

The Typical Process of Gastrulation, as in Sea-Urchin. A hollow ball of cells, a blastula (1), becomes through inequalities of growth (2) indimpled or invaginated. The result is a gastrula, with two layers of cells, ectoderm to the outside and endoderm to the inside. The cavity of the gastrula, the archenteron, becomes the digestive cavity. The opening of the gastrula is called the blastopore.

Lancelet (Amphioxus), its mode of appearance is beautifully clear. It arises in the main in the form of pouches from the archenteron, which lose their connection with their origin, and form the body-cavity or cœlom between the gut and the body-wall. The inner (splanchnic) wall of a typical cœlom-pouch enswathes the food-canal or gut; the outer (somatic) wall clings to the ectoderm and forms the under-skin or dermis; the dorsal portions of the pouches form the bulk of the body-musculature.

In some other cases the outgrowths or pouchings are solid to start with. In the earthworm's development the mesoderm is due to a few primary "mesoblasts", cells which appear at an early stage between ectoderm and endoderm and multiply there to form muscular tissue and the like. In many cases, as in Echinoderms, there are, in addition to pouches, numerous "mesenchyme" cells, separated off individually from the walls of the blastula or gastrula. In almost all animals that have a cavity between the gut and the body-wall, the mesoderm lines that cavity.

WHAT THE GERMINAL LAYERS FORM.—The diversity among animals is great and the detailed differences in their individual development are very striking, yet it is noteworthy that there is a deep similarity in the outcome of the three germinal layers. They have a character or stamp, primarily dependent on their relative positions, and in widely separated types they form the same structures. For backboned animals the embryological origins may be summed up:

(*a*) The *ectoderm* gives rise to the epidermis or outer skin and its outgrowths, such as hair and feathers; the whole of the nervous

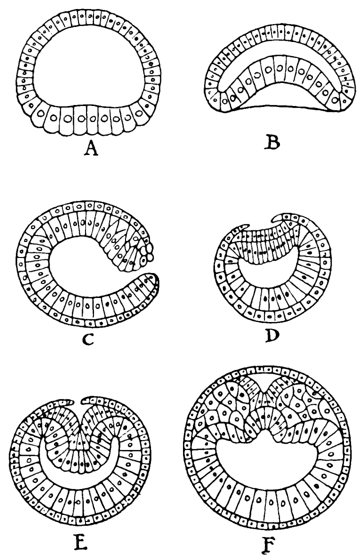


FIG. 119.

Early Development of Amphioxus. After Hatschek. A Primitive Vertebrate. The blastula (A) becomes invaginated to form the gastrula (B). The gastrula shows further differentiation, such as the formation of a dorso-median neural plate (C, D). In E and F a suggestion of the origin of the mesodermic pouches from the primitive gut or archenteron, of the origin of the neural canal, and of the notochord or primary axis being folded off from the roof of the archenteron.

system; the most essential parts of the sense-organs, such as the retina and the lens; an infolding or "fore-gut" at the mouth and a trace of a "hind-gut" at the posterior end.

(*b*) The *endoderm* gives rise to the mid-gut, which in Vertebrates is practically the whole food-canal; the foundations of the many pouches or diverticula that grow out from the gut, such as liver and pancreas; and, somewhat surprisingly, an axial skeletal rod, in most cases the predecessor of the mesodermic backbone.

(*c*) It is convenient to take ectoderm and endoderm first, for then one can say that the *mesoderm* forms all the rest, e.g. the under-skin or dermis; the muscles; the connective tissue; the bony skeleton;

the lining of the body-cavity and the enswathing of the food-canal; the kidneys; the blood, the heart, and the blood-vessels. In the case of outgrowths from the embryonic gut, the outside of each pocket must be the mesodermic enswathing, so that all these pouchings are in part endodermic and in part mesodermic. Similarly, the mesodermic backbone, if there is one, develops around the endodermic notochord, which it replaces in whole or in part. Connective tissues, vascular system, and unstriped muscles are formed from mesenchyme cells (see above). In triploblastic animals the essential reproductive organs or gonads are associated with the mesoderm, the ovaries or testes developing on the wall of the body-cavity. But it is clearer to keep the origin of the gonads apart from that of the other organs or tissues. They arise from an early segregation of primitive germ-cells, which take no part in body-making.

GENERALISATIONS.—(1) The ovum-theory or cell-theory is a biological commonplace, though it should also be a problem; yet it is an unfamiliar fact to the ordinary citizen that every multicellular animal, if reproduced in the ordinary way, starts in life as a single cell—the fertilised ovum. The Metazoa begin where the Protozoa leave off—as single cells. Fertilisation does not make the egg-cell double; there is merely a more complex and more vitalised nucleus than before. All development takes place by the division of the fertilised egg-cell and of its descendant cells. *Omnis cellula e cellula;* and *omne ovum ex ovo.*

(2) Gastræa Theory. As we have already noticed, there is in many types a more or less clearly marked gastrula stage—a two-layered sac of cells. This led Haeckel to suggest that the ancestor of many-celled animals was gastrula-like; and he called the hypothetical primitive form the *gastræa.* He regarded the ontogenetic gastrula as the individual's recapitulation of the phylogenetic gastræa. There is nothing far-fetched in this hypothesis, for the Metazoa must have begun somehow, and some very simple forms like Protohydra and even certain Turbellarian worms are not far removed from elongated gastrulæ. It is not inconsistent with Haeckel's theory to suppose that there may have been other primitive forms of Metazoa, such as a hollow ball of cells like the common Volvox of to-day. But a diploblastic thimble-like sac with a mouth is nearer the simplest Metazoa now living, and on general grounds it must be regarded as a promising presumptive ancestor. The speculation must be supplemented, however, by an inquiry into the actual conditions operative to-day and in the distant past, that may account for the invagination of a blastula to form a gastrula. One of these conditions may be found in the more rapid division of the cells of the upper, less yolk-laden hemisphere of the ball.

ORGANIC CONTINUITY.—The largest fact in heredity is the tendency of like to beget like. Not only is there a general persistence of specific characteristics from generation to generation, but minute features, idiosyncrasies, and some pathological conditions, inborn in the parents, may recur in the offspring.

The reason for this persistence is very clearly seen in some types which show what Weismann called "germinal continuity". At an early stage in the development of the embryo of certain types, the future reproductive cells of the organism are distinguishable from those that are forming the body. The somatic cells develop in manifold diversity, various hereditary characters finding expression in the cytoplasm of each type—nervous, muscular, skeletal, and so forth. In short, division of labour is established, and the body-forming cells lose their likeness to the fertilised ovum of which they are all, of course, lineal descendants. On the other hand, the future

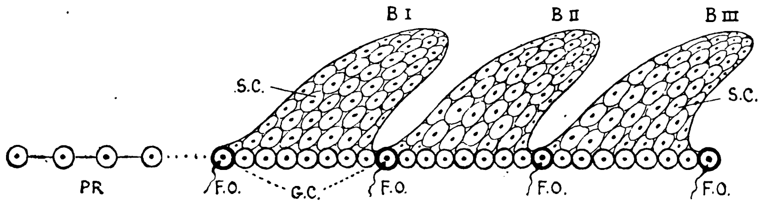


FIG. 120.

Diagram of the Continuity of the Germ-Cell Lineage. PR, a succession of unicellular organisms. To the right a succession of three multicellular organisms each arising from a fertilised ovum (FO); the lineage of the germ-cells (GC) is indicated by the basal row; SC, the somatic or body-cells of the successive individuals (B I, B II, B III).

reproductive cells are not implicated in forming the "body", but, remaining virtually unchanged, continue the hereditary tradition intact, and are thus able to start an offspring which must resemble the parent, since it is made out of the same kind of material and develops under similar conditions.

An early isolation of unspecialised reproductive cells has been observed in the development of numerous types, e.g. threadworms, leeches, arrow-worms, Polyzoa, some crustaceans (e.g. Cyclops and Moina), some insects (e.g. Chironomus, the harlequin fly), Phalangidæ among Arachnids, *Micrometrus aggregatus* among Teleostean fishes; and with less distinctness in some others. A cell that gives rise to all the future reproductive cells is demonstrable in the gastrula stage of Cyclops and among the first sixteen blastomeres in the threadworm Ascaris. If the fertilised ovum has certain prospective characters or hereditary initiatives, say, a, b, c, . . . x, y, z, then the single cell just referred to will have them, and so will the cells to which it gives origin, including those liberated to form a new generation. This is why like begets like.

In many cases, however, the reproductive cells are not recognisable as such until a relatively late stage in development, and after the differentiation of the body has made considerable progress. Weismann's suggestion for such cases was simply that the reproductive cells which form at a later stage the gonads of the offspring, are those cells in whose nuclei there persists an intact or complete representation of the qualities of the fertilised ovum which developed into the said offspring. In plants and in simple animals like zoophytes, there is a widespread persistence of this embryonic type of cell, in which the cytoplasmic differentiation has not gone too far to prevent in appropriate conditions the development of the complete set of hereditary factors carried by the nuclear chromosomes. Hence the familiar facility of asexual multiplication in such types, and the rearing of a complete new organism from a representative fragment, such as a portion of a Begonia leaf or an eighth of a Hydra polyp.

This idea of the continuity of the germ-plasm is of great importance in enabling us to understand the fundamental fact that a specific organisation persists. The parent is rather the trustee of the germ-plasm than the producer of the offspring, though the complementary nurturing factor is, of course, emphasised in cases like the gestation of mammals.

The idea which Weismann made current coin had been previously hinted at—by Owen, Haeckel, Rauber, Jaeger, Nussbaum, and Brooks; and it was clearly stated in 1875 by Galton, who pointed out that the child is, in a sense, as old as the parent; for when the parent's body is developing from the fertilised ovum, a residue of unaltered germinal material is kept apart to form the reproductive cells, one of which may become the starting-point of a child. But for practical purposes it was Weismann (1885) who made the idea one of the foundation-stones of biology: "In development a part of the germ-plasm contained in the parent egg-cell is not used up in the construction of the body of the offspring, but is reserved unchanged for the formation of the germ-cells of the following generation."

RECAPITULATION DOCTRINE.—Long before the evolution idea was accepted by zoologists, the idea was mooted (e.g. by Meckel in 1821) that the stages in individual development correspond to grades of organisation in the animal kingdom. Von Baer called attention to common features observable in vertebrate embryos in early stages, but he indicated at the same time that there was a remarkable specificity almost from the first. Louis Agassiz, in his essay on Classification (London, 1859), expressed his belief in a correspondence between stages in embryonic development and the grades of differentiation recognised in the classifica-

tion of living and extinct animals. Though no evolutionist, he wrote:

"It may therefore be considered as a general fact, very likely to be more fully illustrated as investigators cover a wider ground, that the phases of development of all living animals correspond to the order of succession of their extinct representatives in past geological times."

His son, Alexander Agassiz, compared stages in the development of Echinoderms with the fossil series, and said:

"Comparing the embryonic development with the palæontological one, we find a remarkable similarity."

To Haeckel, in particular, credit is due for recognising the importance of the recapitulation doctrine and stating it clearly in the light of evolution. He called it "the fundamental law of biogenesis" ("biogenetisches Grundgesetz"), and stated it in the familiar words: "Ontogeny is a recapitulation of phylogeny." He also introduced the idea of palingenetic characters, which correspond to those of the ancestral stock, and kainogenetic characters, which are relatively recent additions. The latter, he said, may disguise the former in a perplexing way; in any case, the recapitulation is general, not exact, and often shows great condensation. Fritz Müller was another who did much (e.g. in his *Für Darwin*, Leipzig, 1864) to illustrate and corroborate the recapitulation idea.

This doctrine has suffered considerably at the hands of its friends, who have sometimes stated it in an exaggerated and inaccurate way. When Milnes Marshall said, "Every animal in its own development repeats its history, climbs up its own genealogical tree", he was speaking picturesquely, for the recapitulation is general, not detailed; it often shows telescoping, and it is truer of stages in organogenesis than of stages in the development of the embryo as a whole. It is hardly necessary to say that a developing bird is never like a reptile, but only like an embryo reptile. It has also to be remembered that one term in the comparison, the phylogeny, is very imperfectly known, so that assertions as to the exactness of the recapitulation must be taken with much reserve. And, again, the illustrations that have been adduced have not always been very happy. The simplest animals are like single cells; there are some balls of cells, like Volvox, on the border-line between unicellulars and multicellulars; and there are some very simple two-layered sacs of cells, such as Protohydra. But, when we see an animal of relatively high degree, such as the primitive vertebrate Amphioxus, beginning its life as a fertilised egg-cell, which develops into a ball of cells (blastula) and a two-layered sac of cells (gastrula), we are probably mistaken in regarding this as a recapitulation of very ancient phylogeny. Reproduction by means of isolated germ-cells need not have any historical reference to the Protozoa; a ball of cells may be the

physiologically necessary result of the cleavage of an ovum when it is not encumbered with too much yolk; and it is possible to account for the formation of a gastrula without dragging in the hypothetical ancestral gastræa. The disc-like blastoderm familiar in birds and reptiles has no probable reference to a primeval platelet or placula stage in the evolution of Metazoa.

An important criticism concerns *specificity*, i.e. the individuality and uniqueness of every well-defined type. A fish may be identified by a few scales, a bird by a few feathers. The cells lining the windpipe of a horse are readily distinguishable from those of a dog, and the palate of a land-snail from that of a periwinkle. There is pronounced chemical individuality in species, as may be detected in the milk of nearly related mammals or the juice of the grapes in nearly related vines. It is most literally true that "all flesh is not the same flesh". There is no doubt that increased precision of embryological work has disclosed the individuality or specificity of the organism even in early stages of ontogeny. Thus the number of chromosomes within the nucleus of a cell is, with few exceptions, constant for each kind of organism, and the embryo of a mouse could thus be distinguished from that of a rabbit, or that of an onion from that of a lily. But a recognition of the fact that an organism is from the start itself and no other is not inconsistent with admitting a significant correspondence between steps in individual development and steps in racial evolution. A tadpole is from the first in several ways an amphibian and not a fish, and yet in its two-chambered heart and branchial circulation it is for a time distinctly piscine.

One reason why the ontogenetic recapitulation of phylogeny must be general, not precise, is that the successive gains made in the course of racial evolution are not superimposed one upon another, but are severally incorporated into the organisation and unified with it. The additions from millennium to millennium are not like new wings added to a house, for the tenements which we call individuals are continually dissolved, and there is reunification at the start of each new life. Yet whatever further saving clauses may have to be appended to the "recapitulation doctrine", the broad fact remains that ontogeny is the making explicit of the germinal organisation, which is what it is because of phylogeny. The past lives on in the present in a manner peculiar to and characteristic of living creatures, and it is because it is determined by the past that an embryo moves towards a goal as if it had the future consciously in view. The ages that are gone have bent the bow in the plane along which the arrow of the individual flies. But ontogeny must not be thought of as the uncoiling of a wound-up spring, or as the unpacking of a marvellous treasure-box; it is a function of the individuality which is somehow condensed within the germ-cell.

It is the transformation of the germinal organisation into the adult organisation, and it implies a series of steps in differentiation and integration. The fundamental fact which we are so far from understanding is that the fertilised ovum is at once the repository of ages of organic inventions and a unified individuality in the one-celled stage of its becoming.

MODERN TRENDS IN EMBRYOLOGY.—The old-fashioned morphological embryography has largely given place to experimental and physiological studies of development; but the structural (anatomical and histological) description of the stages in a life-history can never cease to be an integral part of biology. Johann Schmidt's masterly elucidation of the larval development of the Common Eel has much interest even for the general biologist, and Leiper's discovery of the story of the aberrant Trematode Bilharzia is notable in itself, as well as in its practical applications. Of recent years there has been no more striking achievement than Isabella Gordon's description of the building up of the sea-urchin's test, from a few spicules in the free-swimming larva to the elaborate edifice of the adult.

Notable advances have rewarded the applications of physiological methods and ideas to embryology. There has been a fruitful study of the regulative and "organising" influence of one part on another during development, of the rôle of hormones in controlling the rate and rhythm of developmental changes, of the significance of certain environmental factors and chemical substances in the food. The studies of Julian Huxley and others on de-differentiation and regeneration illustrate the modern movement, and the experiments of Spemann are outstanding. A few particular discoveries may be mentioned. (*a*) In many cases, up to frogs, it is possible to induce a quite normal development of eggs, although these have not been fertilised. (*b*) Many experiments show that a part of an egg may be as good as the whole. A larva may be reared from a fertilised fragment of an Echinoid egg, or from one of the first four cells into which the ovum of Amphioxus divides. (*c*) In certain cases, as in Ctenophores and Tunicates, it is possible to prove that there are specific organ-forming substances or building-materials in an egg, whose removal is followed by some particular defect in the developing organism. (*d*) A portion of the optic vesicle of a tadpole grafted under the skin of the larva in an entirely irrelevant place, such as the side of the body, will induce in the cells of the epidermis the formation of a lens; and this evoking of lens-formation is the normal function of the optic vesicle in its proper place.

(*e*) If the newly fertilised eggs of the American Minnow (Fundulus) are exposed for a few hours to a temperature a little above freezing-point, a percentage will develop into blind larvæ. This

experiment is enough in itself to show that the blindness of certain cave fishes need not necessarily be ascribed to the darkness; it might readily arise in response to some penetrating environmental change, such as low temperature. (*f*) If the developing eggs of the same fish (Fundulus) are subjected to various reagents, such as butyric acid, there result numerous strange monstrosities in eyes and ears, nostrils and mouth, even in heart and fins. The chemical intrusion seems to dislocate and partially dissolve the germinal material, especially towards the head end. This may throw some light on monstrosities, for butyric acid derivatives appear in higher animals as the result of some disturbance in the carbohydrate metabolism, and a consequent poisoning of the mammalian mother's constitution might result in monstrosities in the early embryo. On a similar but very different line, some interesting light has been thrown on the development of galls in plants; the tissues react in a specific way to the salivary secretion of the larva of the gall-fly. (*g*) If the larva of the blind newt Proteus be reared in the laboratory under red light, the eye, which is normally arrested in the darkness of the caves, increases in size, reaches the surface, and may continue its development to the extent of becoming a seeing eye. The reason for the red light is that in white light the skin becomes darkly pigmented, which shuts off the stimulus from the developing eye, so that its differentiation is not continued. (*h*) According to Baltzer's account of the development of the green worm Bonellia, notable for its extraordinary sex dimorphism, those free-swimming larvæ that settle down on the floor of the sea develop into large green females with a body an inch or two in length and a flexible food-capturing proboscis which may be a foot long. But those that settle down on the proboscis of a full-grown female and begin to absorb the skin-secretion have their development inhibited, and become pigmy males. Those larvæ that Baltzer helped to attach themselves to the proboscis of a full-grown female, but left attached for a very short time, subsequently developed into almost perfect females. Those that he left attached for a long time became the ordinary pigmy males, with unrecognisably simplified structure, which live parasitically in the female. But those that Baltzer left for intermediate intervals of time showed various stages of inter-sex. Goldschmidt's criticisms have to be considered, but the main facts seem to be secure.

There is more than verbal progress in the recognition that embryology cannot be limited to the study of the young animal. It is plain that the larval stages must also be included, and the difficult phenomena of metamorphosis. But one cannot logically exclude such strange dis-organisations and re-differentiations as are involved, for instance, in the "brown body" of many Polyzoa or in the seasonal relapse and rejuvenescence of some Tunicates. The

changes of adolescence cannot be separated off from their antecedents, and thus the broader view of embryology must include the study of the whole organism in its time-relations, even those of senescence. The fine work of Child on *Senescence and Rejuvenescence* is significant. As we shall notice later on, it is biologically interesting to compare the life-histories of different types, for they sometimes differ from one another in the relative length of the various arcs on the life-curve. Thus some, like Peripatus and the elephant, have a prolonged embryonic period; others, like the lamprey, show a lengthened-out larval phase; others a long adolescence, and so on. Some, like eels, die abruptly after reproduction, while others continue parental for many years. Some practically telescope the whole youthful period; others, as in many fishes, continue steadily growing till they come to a violent end.

EXPERIMENTAL EMBRYOLOGY ILLUSTRATED

The first task of the embryologist is to describe the development of the individual organism from stage to stage. He tells us by what steps the frog's egg develops into a tadpole, and the tadpole into a frogling. Literally and metaphorically, he takes cross-sections at successive times; and the recombination of these discloses the sequence of individual "becoming". The methods of anatomy and histology afford successive pictures, and these, often photographed, are combined, so to speak, into a film. This is the simplest and oldest kind of embryology, and to emphasise its task of describing a succession of chapters, it may be usefully called EMBRYOGRAPHY (see section on the Sub-sciences of Biology).

Gradually, however, though very slowly, the physiological aspect of development became the subject of study. Each stage has to continue the ordinary functioning, e.g. of nutrition and respiration; and the development of one corner of the body is influenced by what is going on in other parts. During each chapter the developing animal has to solve all the fundamental problems of the living creature, except reproduction; though in most cases, save the aquatic, locomotion also remains in abeyance. Moreover, the embryologist's description is very inadequate unless he takes account of the mutual influence of parts (correlation), and the associated harmonising of the development of different parts (regulation).

Thus each step in the development of an organism is a function of three factors: (*a*) the specific organisation of the germ-cells, sometimes hinted at by a visible complexity of structure, e.g. in the chromosomes, but with an inconceivable intricacy of molecular complexity beneath this; (*b*) the vital relations of the various blastomeres or segmentation cells to one another, as they multiply;

and (*c*) the environmental influences (pressure, osmosis, chemical composition of the medium, aëration, temperature, light, and so forth) which play upon the developing whole. By ingenious methods the experimental embryologists have of recent years greatly advanced our understanding of these factors.

As a method in investigating both the structural and the functional aspects of development, experiments have proved very illuminating, and they have been of many kinds, utilised at many different levels. It is convenient to refer to these under the title *Experimental Embryology*; though it is plain enough that this does not form a *subdivision* of Embryology. There is anatomical embryography and physiological embryography; but "experimental embryology" is simply a summation of the results reached by using experimental methods. It is thus not a distinct department, but simply the application of various technical methods, as of modifying environment, etc., etc., so often giving rise to changes of function, and even form, by which fresh light is often thrown upon the normal physiology and anatomy of the embryo.

Here the fullest order of treatment would begin with the earliest stages of development, and work onwards; showing how experiments have been made with the maturation of the germ-cells, their fertilisation, their segmentation, the establishment of germinal layers, the process of organogenesis, and so onwards in development. Yet, as more within the limits of this introductory outline, let us give examples of different *kinds* of experiments, and arrange these as far as possible in the order of their application. This has the advantage of gradually leading up to the most modern experiments, notably those of Spemann, which are certainly the subtlest and most suggestive.

(1) MONSTROSITIES.—The idea of interfering with the embryo is an old one. Thus Swammerdam in the seventeenth century is said to have succeeded in producing monstrosities; but for practical purposes this type of experimental embryology dates from the last quarter of the nineteenth century, with Dareste (*Récherches sur la production artificielle des Monstruosités; ou Essais de Tératogénie Expérimentale*, Paris, 1877). He experimented chiefly with the developing egg of the fowl, placing it vertically instead of horizontally, keeping it slightly above or slightly below the normal temperature of incubation, heating different parts unequally, hermetically varnishing part of the shell, and so on. His suggestive work was justified in two ways, first in the production of sundry malformations which throw light on normal development, and second in showing that the developing embryo is plastic, yielding to changes in its environment. Development is thus a resultant of hereditary nature and environing "nurture" in the widest sense.

The next pioneering inquiry was A. Rauber's *Formbildung und*

Formstörung (1880), in which the results of abnormal disturbances were again utilised to throw light on the causes of normal development, showing how artificial *deforming* might aid in the understanding of normal *forming*. We must also refer to the important work of W. His (*Unsere Körperform*). Thus he sought to show how the amount and disposition of yolk, the pressure of membranes, the mutual influences of parts, and the environmental stimuli were factors in causing foldings and pouchings, ingrowths and outgrowths, and other processes of development. Thus, to take a simple case, if there is a considerable amount of yolk in an egg-cell, as in the frog's, it will sink to the lower hemisphere, and will there inhibit the rate of egg-cleavage. The resulting ball of cells will show an upper hemisphere of numerous small cells, and a lower hemisphere of a few large yolk-laden cells. The continuation of this inequality of growth will necessarily lead to an overgrowth on the part of the smaller cells.

The work of His was an attempt to correlate the potentialities of the embryo with its conditions of development, and thus rationalise each advancing phase of growth and change: an obviously sound and necessary inquiry, illuminating the life-process. Though this was not at first appreciated by previous observers (since their evolutionary interest was too purely morphological), His was soon the inspirer of workers activated by this physiological view. Rauber's contribution was to corroborate the physiological interpretation of the normal course of development by data derived from teratogenic (i.e. monstrosity-making) experiments.

(2) PUNCTURING EXPERIMENTS.—When Roux punctured one of the first two segmentation cells into which a frog's egg divides, he found that the intact other cell developed into a *half*-embryo. Thus it might show half of the normal cerebrum, one ear-sac, a one-sided gut, and so on. But when Oscar Hertwig destroyed one of the first two segmentation-cells, the surviving half formed a fairly normal embryo of dwarf size, but not a *half*-embryo. Observers of equal competence working with the same material reached discrepant results. But T. H. Morgan proceeded to show that either a *half*-embryo or a whole half-sized dwarf may result from the experiment, according to whether the uninjured blastomere was kept in a fixed position (Roux), or allowed to move freely in the water (Hertwig), so that rearrangement of egg-materials was effected.

(3) ISOLATION EXPERIMENTS.—Some striking results have been obtained by shaking apart or otherwise isolating the segmentation-cells into which an egg-cell divides, and no instance is more instructive than the work of E. B. Wilson on the developing ova of the lancelet or Amphioxus.

The early stages in the development of Amphioxus are as interest-

ing as the larvæ and the adults. For there is great plasticity in the processes of cleavage, and the embryo adapts itself readily to the tricks of the experimenter who isolates or disarranges the segmentation-cells. Thus, in illustration of plasticity, it may be noticed that the third or equatorial cleavage, which divides four equal segmentation-cells into four smaller cells or micromeres and four larger cells or macromeres, results in three different arrangements of the eight cells—radial (as in some Echinoderms), bilateral (as in Tunicates and Cephalopods), and spiral (as in Polyclads and Annelids). These three types are connected by every conceivable transition.

After explaining that it is necessary to shake the eggs *gently* if one would succeed in isolating blastomeres, and that there is a risk of being led astray by broken fragments of blastomeres, Wilson gives an account of the induced forms reared from isolated segmentation-cells. It will be convenient to speak of the first two blastomeres as half-blastomeres, of the first four as quarter-blastomeres, and so on.

An isolated half-blastomere undergoes cleavage identical with, or approximating to, that of a normal embryo, forming a normal blastula, gastrula, and fairly normal larva, each a half of the usual size.

Dislocation without separation of the two half-blastomeres results in variously disposed double embryos like Siamese twins.

An isolated quarter-blastomere often varies in its cleavage more or less widely from that of an ovum. It may give rise to a blastula and gastrula, differing from the normal only in size, but a segmental embryo was rarely formed, and a larva with a notochord, neural canal, and mesoblastic somites was only once obtained.

A four-cell stage, separated into two pairs of cells, may give rise to two perfect half-sized dwarfs. Incomplete separation of the quarter-blastomeres gives rise to double embryos, triple embryos (one twice the size of each of the others), and rarely to quadruple embryos. The double and triple forms may attain to the gastrula stage; the quadruple forms did not rise beyond blastulæ. In three cases gastrulæ of about one-eighth the normal size were formed from shaking the four-celled stage, probably from a broken quarter-blastomere.

An isolated one-eighth-blastomere, which may be a macromere or a micromere, segments in a manner approaching that of a complete ovum, but never identical with it. In rare cases blastulæ were formed, living for two to three days; usually flat or curved ciliated plates, like fragments of epiblast or hypoblast, were formed, which swam about actively, and lived for twelve to eighteen hours. Dislocation of the blastomeres at this stage gave rise to a great variety of forms: the isolated blastomeres of the 16-cell stage gave rise to numerous forms, including minute blastulæ. Usually flattened plates or shapeless masses resulted.

It may be of interest to note that soon after isolation the blastomeres frequently explode with violence into minute granules, a fact which suggests the high tension of the cells.

A general result of importance is that the isolated blastomeres undergo a cleavage that approximates more or less nearly to that of a normal ovum, but the extent of divergence is nearly proportional to the age of the initial form.

"Even a slight displacement of the blastomeres in the 2-celled stage causes a change in the form of cleavage, such that the blastomeres of the half-embryo cannot be identified individually with those of a normal embryo half. The normal embryo develops as a unit; if it be disturbed in the 2-celled stage this unity is destroyed, and two new units are established."

"The unity of the normal embryo is not caused by a mere juxtaposition of cells"; thus only one of the blastomeres of the 2-celled stage may develop, e.g. into a gastrula, the unsegmented blastomere remaining attached. "The unity is not mechanical, but physiological; there must be a structural continuity from cell to cell that is the medium of co-ordination, and that is broken by mechanical displacements of the blastomeres."

Lastly, as regards concrete results, it should be noted that "all the induced forms of development show in general a lack of developmental power, which becomes more pronounced as the ontogeny advances".

(4) Pressure Experiments.—Deformations of embryos may be afterwards righted by regulative influences, but teratogenic conditions, which are past mending, may also be induced by artificial changes of pressure.

(5) Radiations.—Many different kinds of radiations have been shown to be influential. Thus increased temperature may induce twinning and increased illumination may cause the albino larvæ of Proteus to develop pigment. Some radium rays are lethal, while others provoke variations.

(6) Chemical Stimuli.—Changes in the chemical medium may have all sorts of influences, from the production of monstrosities to a quickening of normal development or a provocation of new departures.

(7) Grafting.—Very interesting results have rewarded grafting experiments, such as the evocation of a lens when a piece of tadpole's optic vesicle is cut off and re-implanted under the skin of the side of the body.

SPEMANN'S IDEA OF "ORGANISERS."—One of the new ideas that has rewarded grafting experiments on embryos is Spemann's idea of "organisers". To explain this, it is necessary to go back to a little elementary embryology—the story of the early stages in the development of the frog.

The egg-cell of the frog is about a tenth of an inch in diameter, and is surrounded by a delicate cell-membrane, a tougher follicular membrane, and, outside that, the jelly or albumen of the spawn. There is a considerable quantity of yolk, which sinks to the lower hemisphere of the egg ("the vegetative pole"), which has a lighter colour than the upper hemisphere ("the animal pole"). When fertilisation occurs, at the time when the eggs are liberated by the female frog on whom the male is mounted, the vitelline membrane rises from off the surface of the egg, which is thus able to rotate, keeping the heavier vegetative pole always lowest.

Where the spermatozoon enters is of importance in relation to subsequent symmetry; for it marks the future ventral surface. Diametrically opposite, there is a retreat of pigment into the egg, forming a so-called "grey crescent", which marks the future dorsal side. The animal pole will become the head-end and the vegetative pole the tail-end.

Segmentation is total and unequal. The upper hemisphere shows numerous small cells; the lower hemisphere has fewer larger cells. Between the two and internally there is the small blastula cavity nearer the upper surface.

The cells of the animal hemisphere divide more rapidly than those of the vegetative hemisphere, and thus grow over the lighter-coloured cells, which become less and less visible. At the centre of the grey crescent there is a slight lip, below which an ingrowth of cells gradually begins to establish the inner germinal layer or endoderm —which becomes the lining of the embryonic gut, the archenteron. This intucking corresponds to the invagination of a blastula to form a gastrula, and the lip corresponds to the dorsal side of the gastrula-mouth or blastopore. This lip spreads to right and left of its first appearance; the overgrowing dark cells cover the yolk cells more and more towards the vegetative pole—till they are only visible as a small circular patch—the "yolk-plug". The curved ends of the spreading dorsal lip meet on the ventral side of the yolk-plug, so that there is a complete dark ring round the yolk-plug.

Meanwhile the ingrowth of endoderm-forming cells is going on, especially on the dorsal side, forming a dorsal wall for the archenteron, of which the yolk-laden cells are forming the lower portion. This is really a gastrula formation, disguised by the relatively large amount of yolk; and during this process the whole egg rotates, so that its original vertical axis comes to be more or less horizontal.

Along the dorsal-median line of the archenteron a supporting rod of cells is now folded off; this is the beginning of the primitive skeletal axis, the notochord; an endodermic rod, eventually replaced by its mesodermic substitute, the vertebral column.

Split off from each side of the archenteron is a layer of cells, the mesoderm, which spreads between the ectoderm and the endoderm.

This mesoderm becomes divided into an inner layer, which clings to the gut, forming its muscular sheath, and an outer layer that clings to the skin, forming the dermis. The cavity between these two layers is the body-cavity.

The folding off of the notochord, and that of the mesoderm, alike proceed from the anterior region backwards; and they merge posteriorly in the rim of the blastopore, where there is a zone of actively growing cells, which contribute to all the three germinal layers—ectoderm, mesoderm, and endoderm. This activity on the part of the blastopore-lip tends to the elongation of the embryo; and this activity continues even after the blastopore lips draw together into a narrow slit and then close altogether.

Meanwhile changes are proceeding along the middle-dorsal line of the ectoderm. A neural plate becomes by unequal growth a neural groove, and the neural folds bounding this groove bend towards one another, to form the walls of the neural canal, of which the anterior part widens into the brain; while posteriorly the two neural folds grow around the blastopore.

All this preamble, which will become clear if good figures are carefully studied, is necessary to an understanding of one of the most interesting results of Spemann's experiments. In early embryonic stages, before gastrulation, there is great plasticity. It is not irrevocably settled what a particular patch of cells will form, if its position in the embryo is altered. In other words, differentiation is not yet irreversible.

But in the few hours of gastrula-formation this early plasticity disappears. By a sudden change "the germ loses its capacity for regulation, and becomes a sort of jig-saw of separate parts, each predetermined to produce just one particular organ of the future tadpole". This sudden change has been traced by Spemann to the influence of the active cells of the dorsal lip region.

Spemann showed that if the minute dorsal lip-region of the frog or newt embryo be grafted upon, say, the flank region of another embryo, it there induces the development of an extra set of dorsal organs—such as neural canal and notochord, and of other structures as well, even to muscle segments and kidney-tubes. In fact, at first sight it looks as if this graft were starting a second embryo. But these new structures are not formed *from* the grafted fragment, but arise in the tissues (thus abnormally stimulated) in contact with it, and which were in course of their normal and quite different development. By reason of this strange and potent influence of this particular grafted portion of one embryo upon some independent portion of another, Spemann called the former an "organisator".

Two points should be emphasised: (1) that in the frog embryo no region but the dorsal lip-area has this organising power; and (2) that it has this power when it is the most active part of the

embryo, e.g. with very rapid cell-division. When this is considered along with the facts of axial gradients, say in Planarian worms, it seems likely that the great intensity of activity has to do with the organising power.

The nerve-cord and notochord are normally developed in the meridian of the dorsal lip of the blastopore. By excision and re-implantation of the dorsal lip the "axial organs" may be evoked in a region where they would not be normally developed. Or the excision of the "organiser" and its transplantation into another embryo may be followed by the appearance of the usual axial structures, even in irrelevant positions.

Moreover, transplants from a frog (*Bombinator*) or from an Axolotl (Amblystoma) may operate as influential organisers in a newt embryo. There is something unique in the intensely active dorsal lip zone, but it is difficult to explain the uniqueness.

This difficulty is increased by the fact that if a portion of tissue from some other area, even of a different embryo, be introduced by grafting into this dorsal lip, it can afterwards be excised from it, and be used as an organiser for a third embryo. But here, for the time, the experiments leave us with the question of the nature of this influence. Is it hormonic (or rather pre-hormonic!), or what?

From experiments such as those which we have illustrated it is beginning to be possible to draw conclusions, embryology in the true sense rising by experimental methods out of embryography. In many cases it is clear that the nucleus with its chromosomes is vastly more important than the surrounding cytoplasm, for an intact nucleus with a minute fragment of the egg-cell may develop into a normal embryo, as Delage's merogony experiments show. In other cases, as in the Tunicate Clavellina, there is evidently an early arrangement of building material in the egg-cell, for microscopic vivisection has shown that the removal of a certain segment will result in the absence of a certain structure in the larva. When experimental disturbances have greatly altered the arrangements of the segmentation-cells there may be a striking re-institution of order, so that the outcome is normal. There are indubitable regulative processes in development, as Spemann's work so well shows. One part of an embryo may exert a demonstrable diffusive influence on tissues round about, even when these are not the normal tissue-environment, as is graphically seen when an excised optic vesicle is re-implanted at an irrelevant place.

ORGANIC REGENERATION

The term regeneration is usually and correctly applied to the replacement of lost parts of organisms, whether organs or tissues,

and also to the re-growth of a whole from a separated-off fragment. It implies processes of growth and differentiation, outside the normal course of individual development, though some of its most striking instances are to be found in embryos, rather than in adults.

NOTABLE INSTANCES AMONG ANIMALS.—When a lizard struggles convulsively in a bird's bill, it may reflexly break off its tail, right across a weak plane which traverses the vertebral column, at one place or at several; and it may thus escape. Moreover, the loss implied in the involuntary surrender of a part is not permanent, for the lizard can re-grow a tail. It is true that the re-growth is a make-shift, an unsegmented rod without vertebræ, but it is none the less a tail, and almost as effective as the original in aiding locomotion. There is a formation of new muscles and of new scales; and an interesting point, noted by Boulenger, is that the scales reproduced are sometimes nearer those of an ancestral type. The regeneration is often fairly rapid, thus in the case of some Portuguese geckos which had lost their tails, a re-growth of half an inch—about quarter of the total length, took place in the course of a six weeks' voyage, during which the animals had no food.

As other well-known instances of organic regeneration among animals, we may mention the wounded earthworm's re-growth of a new tail or even head, the starfish's replacement of a lost arm, the crab's restoration of a lost great claw. So the snail can re-grow its horn over and over again, never omitting the little eye at the tip; certain male cuttlefishes renew the sperm-laden arm which is loosened off into the mantle-cavity of the female; and the newt replaces the terminal part of a leg that has been bitten off by a fish. But while it is interesting to recall such striking cases, we must realise that this regenerative capacity is very widely distributed among animals, especially in the lower forms. Nor can this process be sharply demarcated from the healing of wounds; for though our scars express an imperfect superficial renewal of the skin, the underlying tissues are usually well-repaired.

ANALOGOUS PHENOMENA.—Regeneration is not to be thought of as a phenomenon apart. It is linked (*a*) to the normal process of growth, and to that discontinuous growth or budding which becomes asexual multiplication; (*b*) to the multiplicative fragmentation of some sea-anemones, worms, and even starfishes; (*c*) to the continuous replacement of some hard-worked tissues, and to the persistent growth of such structures as a rabbit's front teeth, or our finger-nails; (*d*) to the normal restoration of parts periodically shed, notably the antlers of stags and the posterior body of Palolo worms; and (*e*) to the way in which a nucleated fragment of an egg, or a separated-off blastomere, may form a whole embryo.

SPORADIC DISTRIBUTION OF REGENERATION.—A survey of the renewals of lost parts throughout the animal kingdom at once shows

that it is most marked in the simpler animals, and that it wanes in the more differentiated. It is almost unlimited among sponges, polyps, and certain kinds of worms; whereas it is almost unknown among birds and mammals. The re-growth of new feathers after moulting, or of new hairs after casting, can hardly be reckoned as regeneration in the stricter sense, for they are the outcome of papillæ formed before the moulting or casting, much as next year's foliage is developed from the buds formed in the axils of this year's leaves.

There are several common-sense reasons why the regeneration of lost parts should be rare among highly differentiated animals. (*a*) There is very little persistence of that indifferent or embryonic tissue which is so abundant in simple forms, like Cœlentera. (*b*) In some structures of the more differentiated animals, cell-division has come to a standstill; which would tend to limit the possibility of regeneration after an injury, unless some re-activation should occur at the cut surface or below a protective cap. It may be recalled that the *number* of nerve-cells in a Vertebrate brain does not usually increase after birth; only in very rare cases is there any trace of cell-division; so this almost precludes regeneration after a brain lesion. (*c*) Unused structures and capacities tend to disappear; and as the higher animals are less liable to injury, in virtue of their more effective nervous and locomotor organs—their wits and agility, in fact—they have less need for the persistence of the regenerative capacity, so important to polyps and starfish. (*d*) Again, if it be granted, for the sake of argument in the meantime, that a particular regenerative capacity is gradually evolved as an adaptation, we cannot be surprised at its absence in animals where an injury that implies some cutting or biting is likely to be rapidly fatal. For if an injury is rapidly fatal, a compensatory adaptation could not be readily evolved. If a plump caterpillar is even punctured by a bird's bill, it is likely to die rapidly, though it may escape being swallowed; it is not surprising therefore that caterpillars should show almost no regenerative capacity. Their characteristic protective adaptations, e.g. resemblance to twigs, are directed towards the avoidance of being even punctured. Starfishes and sea-urchins are not very far apart, but whereas starfishes show remarkable regenerative capacity, the only structures that sea-urchins can regenerate are their spines. A reason for this is no doubt that the starfish's five-rayed body is very liable to injury, while the sea-urchin's globe is not; in other words, the only non-fatal injury to which a sea-urchin is liable is the loss of spines.

Yet the presence or absence of regenerative capacity is not wholly a question of little or much differentiation. This may be shown by a few contrasts. Nemertine worms are more highly differentiated than Nematodes, yet regeneration is rife among the former, exceedingly

rare among the latter. Regeneration is common among amphibians, especially among newts, yet it is very rare among fishes. A newt can regenerate most of its leg; a fish cannot even replace a lost scale. Or again, a crab's leg is a structure far more complex than a bird's claw, yet the replacement of a crab's leg is a common occurrence, whereas the replacement of a torn-off claw in birds is almost unknown. The annual replacement of the claws of grouse and ptarmigan (which is all but peculiar to these) is a normal renewal, not a reaction to casual wounding. To take one other instance, earthworms and leeches are not on any very dissimilar level of differentiation, yet regeneration is common and extensive in the former, but limited and very rare in the latter.

If we regard the regenerative capacity as due to the diffuse or localised persistence of some more or less embryonic tissue, or of rejuvenescent cells whose formative factors are readily activated by the stimulus of violence, the puzzle remains—*why this capacity should persist in certain types and not in others.* According to Lessona's suggestion (1868), afterwards elaborated by Weismann, the regenerative capacity tends to persist in those animals and in those parts of animals which are, in the natural conditions of their life, peculiarly liable to non-fatal and frequently recurrent injury. This suggestion, ecological, not physiological, is known as Lessona's Law. As Weismann stated it: "The power of regeneration possessed by an animal or by a part of an animal is regulated by adaptation to the frequency of loss, and to the extent of damage caused by the loss."

In support of this view that the distribution and persistence of the regenerative capacity is *adaptive,* and to be accounted for as the outcome of Natural Selection, a number of concrete examples may be adduced. The autotomy and regeneration of the lizard's tail are very general, in fact almost characteristic of the order. Yet neither occurs in Chamæleons; a fact which may be reasonably correlated with this highly specialised lizard's habit of coiling its tail round a branch. A few other exceptions have been noted; yet more or less similarly explained; thus Werner points out that the regeneration is absent, or very incomplete, in those lizards, like the African Zonurus, which use their tails in defence. A tail used in striking would be less likely to be seized than the ordinary wagging and partially locomotor tail of ordinary long-tailed lizards.

Further survey of cases of regeneration shows its frequent occurrence among long-limbed or long-bodied animals, such as starfishes, brittle-stars, higher crustaceans, sea-spiders, ribbon-worms, and limbless lizards. As Lessona said, these are all peculiarly liable to the frequent recurrence of non-fatal injuries. Some difficult cases remain, no doubt, yet some of these exceptions not only test but eventually corroborate Lessona's rule. Spiders are notably long-limbed, and captured specimens sometimes show autotomy followed

by regeneration; moreover, breakages during moulting are generally made good. Yet since spiders are usually agile and elusive, it is not surprising to find that loss, followed by regeneration, is not characteristic of their order. But when we pass to the distantly related arachnid order of "Harvestmen", or Opiliones, where the limbs are elongated out of all proportion to the body, so that the risks of breakage or seizure are obviously great, we find facile autotomy and characteristic regenerative power. Many similar instances might be given.

Regeneration in Plants.—In the vegetable kingdom the regenerative capacity is so widely distributed that it excites little remark. Every gardener knows that he can easily propagate Begonias by planting—or even laying—a leaf or a fragment of leaf on moist sand or soil, where it speedily develops root-hairs on its under side. These root-hairs normally arise in most species when the leaves come in touch with the damp ground, but not in *Begonia rex*, where, however, they can be experimentally induced. The growing of root-hairs is the first step, and ensures a supply of water before the excised piece of leaf can dry up. The second step is the development of adventitious buds at the cut edge of the leaf; and the number of these can be increased by making several nicks on the chief veins; so upon a single leaf a good many new plants can be grown. Similar experimentation by skilled propagators has been proving that what is familiar, yet seeming exceptional, in the case of Begonias, can be elicited in leaves of many different orders, in which it was never known to occur in Nature, or in cultivation.

As one would expect, the regenerative capacity is expressed in varying degrees. Thus in some types, e.g. flowering plants, the excised leaf or portion can develop root-hairs, but no buds, so that no actual multiplication occurs. This is very limited regeneration, but at the other extreme, as sometimes in the common cuckoo-flower, *Cardamine pratensis*, buds may arise on growing and uninjured leaves. Very interesting in its adaptiveness is the Mexican stonecrop, *Sedum Stahlii*, in which the plump leaves are very loosely attached, and easily jerked off by a slight knock, such as might come from a bird's foot. Such a detached leaf develops adventitious buds which take root. Yet in another species, *S. album*, the leaf has the same power of forming adventitious buds, though their firm attachment in this case robs the regenerative capacity of its usefulness for discontinuous dispersion, though furthering extension in continuity with the parent plant.

In lower plants, such as most mosses, liverworts, and algæ, there is almost unlimited power of directly growing a whole from a part. In higher plants, the first step is usually the formation of an adventitious bud, from leaf or shoot, and in a few cases even from a root.

The annual succession of foliage on perennial plants is, of course, not a case of special regeneration, but a normal and seasonal replacement, due to the buds usually developed in the axils of the full-grown leaves. Yet even here we have all seen renewal of buds after a late spring frost or blight, and the like can be provoked by the propagator. Similarly one must not too sharply separate from the ordinary growth-process what one often sees on an injured tree-stem—the mending of the wound by the slow outgrowth from the cambium layer over the bared wood-surface.

The general impression suggested by the work of "Natura Medicatrix" among plants is that more or less regenerative capacity is almost universal, and may be called forth in exigency, or stimulated by conditions of vegetative exuberance. The frequency of regeneration in plants as compared with animals must be associated with the relatively simple differentiation of most structures, in lower forms especially. In higher forms it is associated with the persistence of large tracts of embryonic or rejuvenescent tissue, such as the cambium layer so familiar to us in tree-stems.

From a detached morphological point of view, the zoologist may claim that much as he might roughly imitate most orders of Flowering Plants by varying the disposition of the tentacles in Cœlenterate polyps, which often recall the plant's axis and appendages, so he may roughly compare the general structural level of plants with that of the Cœlentera among animals. In both groups the regenerative capacity is almost unlimited; and in both the phenomenon of alternation of generations finds its finest expression.

INTERPRETATION.—It used to be believed in the early days of experimental embryology that the divisions of the egg-cell, and of the resulting segmentation cells, were *qualitative.* That is to say, there is a parcelling out and segregation of particular hereditary characteristics, some to one group of cells and some to another, the result being differentiation. This view made it very difficult to understand those cases of re-growth and regeneration where a separated piece gives rise to a complete whole, or an undifferentiated stump gives rise to a complex organ, such as the eye at the tip of a snail's horn. But the idea of qualitative division in ordinary development was erroneous. The nuclei are divided and redivided with meticulous accuracy, a longitudinal half of each chromosome passing to each daughter cell. According to the stimulation that each cell receives from its neighbours, and from elsewhere (e.g. by hormones), and from the environment, there is an evoking of the formative activities of different genes or factors in the chromosomes carried by each and every cell. Thus what evokes an activation of this or that hereditary initiative or gene is the precondition of regeneration; and the line of investigation is to discover what these

activating stimuli are, and why they are present in certain types and parts of the body and not in others.

It seems reasonable and not an evasion of the question to say that some types have more persistent embryonic capacity than others. The ever-youthful meristem tissue in plants is a good illustration; and many animals are more rhythmically rejuvenescent than others.

The regenerative capacity must be linked on (1) to the general growth-tendency, the tendency to repeating the same molecules in similar circumstances; (2) to the process of ordinary indirect cell-division, which secures a continuance of the whole inheritance as far as that is carried by the genes in the chromosomes; and (3) to the frequently expressed tendency to developmental recapitulation, and it is noteworthy that some regenerations are arrested at a stage either ancestral or embryonic.

Since embryonic development is the differentiation of a mass of cells, produced from the division of the egg-cell and of its daughter-cells or blastomeres, and since these are early differentiated into the three germinal layers—ectoderm, mesoderm, and endoderm—there cannot be that simple correspondence between normal ontogeny and regeneration which at first sight appeared to the early students of this problem. For the regeneration of a lost part is taking place in some injured corner of a finished organism, and thus must start from a focus which is very different from an embryonic blastoderm. Thus it may be entirely ectodermic!

These are some of the considerations that lead us to regard the replacement of a lost part as less surprising than it at first sight seems. But the difficulty of its sporadic occurrences requires to be met in another way, and we agree with Weismann in interpreting the distribution of the regenerative capacity as *adaptive*. He generalised and vindicated "Lessona's Law", that regeneration tends to occur in those organisms and in those parts of organisms which are in the natural conditions of their life particularly liable to non-fatal injury. In Weismann's words, "the power of regeneration possessed by an animal or by a part of an animal is regulated by adaptation to the frequency of loss and to the extent of the damage caused by the loss".

LIFE-HISTORIES

THE CURVE OF LIFE.—An individual life has often been compared to an arched bridge, rising to a short level middle stretch, and then descending again. It is comparable to an ascending and a descending curve—a trajectory. For whether we think of plant or animal, of bird or man, there is a time of developing, growing, strengthening, mellowing; and then comes the time of decline,

failing, ageing, and dying. A common animal life-curve shows—embryonic development, tender youth (whether of larval period or infancy), adolescence, love-making, maturity, parentage, full strength, ageing, senescence, death. Parallel to that may be pictured the normal life-curve of a higher plant—embryonic development within the seed, sprouting, growing, leafing, flowering, fruiting, seeding, withering, and dying. The first unifying idea that we wish to suggest is that, on general grounds, every life of a multicellular organism must illustrate something of this ascent and descent, for there is a continual see-saw between waste and repair, nutrition

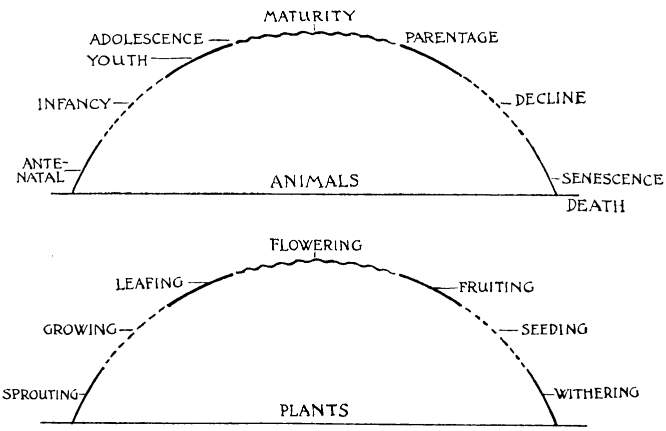


FIG. 121.

Diagram of Typical Life-Curve in Plants and Animals. In the animal curve there is indicated a succession of phases: ante-natal, infancy, youth, adolescence, maturity, parentage, decline, senescence, and death. In the plant curve, similarly, there are indicated: sprouting, growing, leafing, flowering, fruiting, seeding, and withering.

and reproduction, work and rest, the issue of which is that processes of senescence, slowly or quickly, gain on the processes of rejuvenescence. Except in the Protozoa, which seem to be largely immune from Natural Death, senescence always gains on rejuvenescence. The second unifying idea is that the various arcs on the typical life-curve may be thought of as capable of elongation and of shortening in the various types. Thus, one organism may have a prolonged youthful period, and die immediately after reproduction; while another may have a very rapid youth and a long-drawn-out maturity. Moreover, in Backboned Animals (Vertebrata) we know that this lengthening out and telescoping down may be controlled by variations in the hormone-producing endocrinal glands. The cretin's abnormal prolongation of infancy is a sad instance of thyroid deficiency. Thirdly, the strangely diverse life-histories, in some degree unified by these two ideas, have then to be interpreted in

relation to the environmental conditions in which each organism has to live. Thus it is obvious that it is advantageous for animals living in the rough-and-tumble conditions of the seashore to have a prolonged larval period in the relatively safe open sea.

ILLUSTRATIONS.—In many animals there is a disproportionately prolonged youthful period, to a discussion of which we shall return in considering larvæ. What emerges from the egg of a locust, grasshopper, cockroach, or earwig is practically a miniature of the parent, though there may be some differences as regards colour and wings; but what emerges from the egg of a Mayfly is an aquatic larva with little resemblance to the adult. This larva feeds, grows, and moults, but may remain larval for two, three, or perhaps four years. It then changes into a "nymph", and then after a final moult on the bushes by the side of the stream—a moulting unique, since it occurs after the wings have been formed—it puts on the finished adult characters. But this aërial Mayfly is now specialised almost only for reproduction, and dies after an ecstatic evening or two, without a single meal! Truly diagrammatic is the life-curve of one species which has its full-grown life telescoped into one brief hour. It is not even an ephemerid; and yet when the complete curve is kept in view, it cannot be called short-lived.

Among insects there are many instances of prolonged pre-adult stages, and the lengthening out may be in the embryonic, the larval, or the pupal chapter, or even in all of them. In a hive-bee the egg usually takes about 3 days to hatch; the worker-grub is fed and grows for about 6 days; the pupal stage, behind a waxen screen, extends over 12 days; the winged insect is ready to come forth 21 days after the egg was laid; and the worker-bee, after an indoor apprenticeship of about three weeks, issues forth as a forager, exhausting herself in about a month, or at the most six weeks. Some authorities estimate the average summer life of a winged worker-bee at 42 days, which is only twice as long as the antecedent period of preparation.

In some cases, as in butterflies and moths, there is a prolongation of the pre-adult phase or phases, throughout the winter, often in an inactive state. A notorious case is that of the North American "seventeen-year Cicada" (*Cicada septemdecim*), which spends all that time as an underground larva, and then enjoys a brief and noisy aërial existence. Over the States as a whole there is a representation of Cicadas almost every year, but the individual life-cycle is one of seventeen years. Large numbers appear with some regularity every seventeen years, but in other localities, especially to the south, the usual interval is thirteen years—an interesting time-variation which well illustrates our general idea that there are, as it were, elastic arcs on the life-curve. The difference between the 17-year and 13-year varieties of the species may perhaps be correlated with

climatic conditions, but it may merely illustrate a constitutional variation.

Very striking is the prolongation of the ante-natal embryonic period in the case of the viviparous Peripatus, which, with allied genera, represents an early divergence from the ancestral stock leading on to centipedes, millipedes, and insects. The type is a survivor from an ancient fauna, and has persisted partly in virtue of its cryptozoic habits, and partly because of a prolonged gestation, which lasts for about a year, longer even than the antenatal life of a foal within the mare. The advantage is that the young Peripatus is born fully formed and able to look after itself.

The eggs of crabs, e.g. the edible *Cancer pagurus* or the shore crab (*Carcinus mænas*), develop under the shelter of the female's tail, and give rise to Zoæa larvæ which become pelagic. These

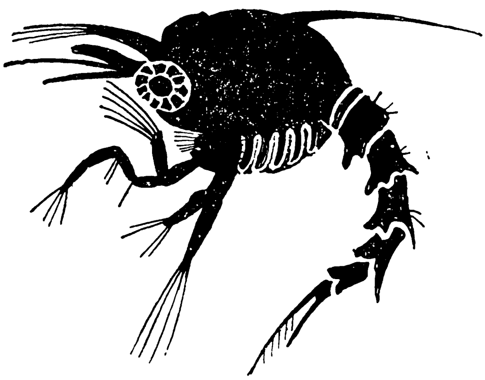


FIG. 122.

Zoæa Larva of a Crab. After Roule. Note the spine rising from the cephalothorax. There are appendages as far back as the last pair of maxillipedes.

feed, grow, and moult, and undergo metamorphosis which results in Megalopa larvæ. Whereas the Zoæa has appendages only as far back as the third foot-jaw (maxillipede), and is marked by a prominent spine on the cephalothorax, the megalopa has lost this spine and has appendages as far back as those corresponding to the last walking legs of an adult crab. Like the zoæa, it carries its posterior body-region (abdomen) in a line with the anterior body-region (cephalothorax), not tucked in as in the adult. Now these megalopas cease to be free-swinging and sink to the floor of the shallow sea. After growing and moulting, they change into miniature but fully formed crabs which creep further shorewards or to the shore itself. In this case there is a long succession of larval stages, but the cycle is contrasted with that of Mayflies, inasmuch as the fully formed crabs may live for many years.

The eggs of lampreys (Petromyzon) develop rapidly and give rise in 10–15 days to minute larvæ. About a month later these are about

half an inch long and leave the stone nest. They burrow into the sand or mud and remain larval for three or four years, differing markedly from the adults, e.g. in having the eyes hidden, in having no teeth, and in the horseshoe shape of the fringed mouth-opening. When 4–6 inches long and 3–5 years old, they undergo a remarkable metamorphosis, putting on the adult characters. The young forms of the river lampreys remain in fresh water, while those of the marine species (*Petromyzon marinus*) go down to the sea, or it may be to a great lake. After two or three years the marine forms are sexually mature and may be a yard long. They return to the rivers to breed, and the reproductive processes of producing and liberating eggs

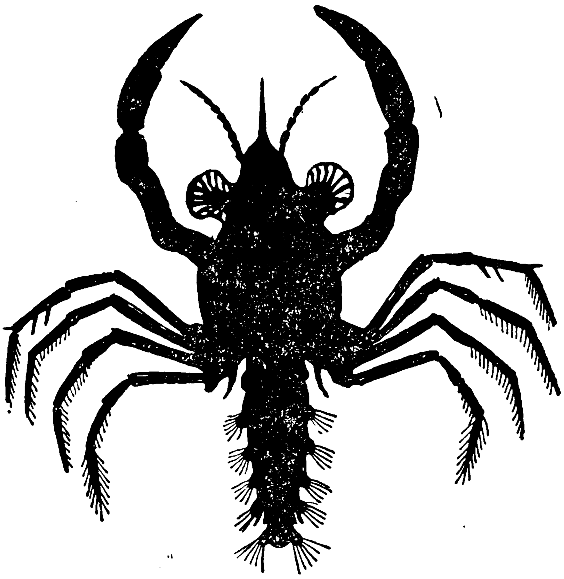


FIG. 123.

Megalopa Larva of a Crab, with the abdomen in a line with the cephalothorax. After Roule.

and sperms are so exhausting that both sexes die after the spawning season. In this case there is a long-drawn-out larval period, and though the adult life is not short, it is abruptly terminated by a coincidence of reproduction and death. The crest of the life-curve is followed by an abrupt vertical descent.

In the life-history of the European salmon there is a lengthening out of several chapters. The eggs are liberated late in the year on the gravelly bed of the river and covered among the pebbles; they are more or less fortuitously fertilised by the attendant male; there is a long-drawn-out embryonic development during the cold months, for cell-division is sluggish when the temperature is low; the eggs are hatched after three months or so—in marked contrast to the lamprey's. Out of the eggs come "alevins", still weighed down by

the large yolk-sac, which furnishes food for a month or two. They cannot swim rightly because of the nutritive reserves in the yolk sac, and they hide among loose stones. When they have absorbed all their store, they have changed into inch-long fry which are able to fend for themselves. By the end of the year those that have been lucky enough and quick enough to survive have become parr, perhaps four inches long, hungry for insect larvæ. They show seven to eleven large bluish marks, oblong or oval in shape, along each side of the body, and this stage continues till the young fishes are about two and a quarter years of age, and are commonly about six inches long. At that time the "finger marks" are masked by a silvery sea-jacket, and there is a change of constitution, expressing

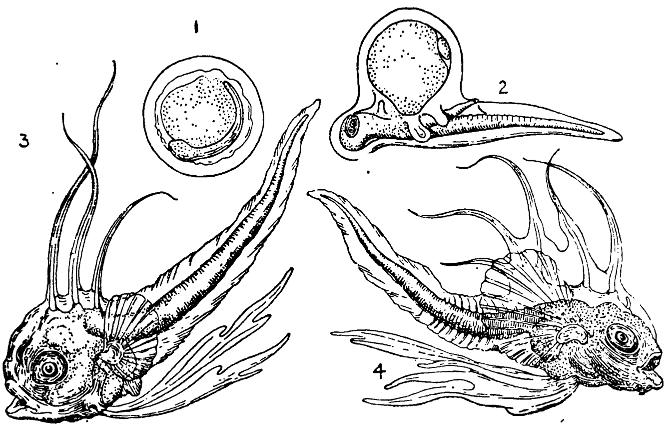


FIG. 124.

Early Stages in the Life-History of Angler-Fish (*Lophius piscatorius*). After Bowman. 1, the floating egg with the embryo fish developing; 2, the hatched larva, with the yolk-sac uppermost in the water; 3 and 4, two pelagic stages, showing the exaggerated tassel-like outgrowths, which probably increase the power of flotation. In this case the larvæ are conspicuously unlike the subsequent adult form, or, what comes to the same thing, their adult parents.

itself in restlessness. In other words, the parr have changed into smolts, which are said to "hear the call of the sea", though we do not know with any precision what this means. Some internal change has pulled the trigger of a hereditary impulse to make for the salt water. In the sea, with a change of diet, the smolts become grilse, but the intermediate stages are little known. A grilse is a young salmon, about three and a half years old, that has not yet quite put on the adult characters. Its scales show, for the period since it entered the sea, a broad summer zone, a narrow winter band, and the beginning of another summer zone. The grilse has not the full shape of a salmon, being more slender towards the tail; and the teeth of the upper jaw are different. It may re-enter the river during the summer and may spawn in the fall of the year; but

some fish pass through their grilse stage without ascending the rivers to spawn. Indeed, they may remain in the sea till they are five or six years old.

The life-story of the salmon varies in detail in different rivers, and is still far from being well understood biologically. But, in any case, there is a very marked alternation between nutrition and reproduction. During the nutritive period in the sea, the fish feed on herring, mackerel, sand-eels, some crustaceans, and the like, accumulating great stores of potential energy, part of which is afterwards expended in swimming against the stream and ascending the rapids. The period in fresh waters is for the adults a time of fasting, more or less strictly observed. But this time of fasting is the time for pairing and multiplying; and here we have a familiar instance of the swing of the vital pendulum: "A time to tear down and a time to build up; a time to preserve and a time to throw away; a time to embrace and a time to refrain from embracing." Let us repeat ourselves: Whether we think of foliage and flowering, or of the voracious caterpillar and the ascetic butterfly, it is the same fundamental antithesis: "A time to seek and a time to lose," an alternation of relatively preponderant anabolism and relatively predominant katabolism. But is there any illustration more dramatic than the contrast between the maiden fish and the spawned kelt? For after the reproduction there is exhaustion and debility, and many drift tail foremost downstream. Even in the short Scotch rivers there is considerable mortality, so that it is not surprising that in the longer rivers of the Pacific Coast, where the upstream journey may extend to a thousand miles, those that go far never survive reproduction. Thus while our European species often succeeds in evading the nemesis that tends to follow reproduction, and may reach an age of even eight years, there is in the Pacific species the same vertical drop of the curve that we noticed in Mayfly and lamprey.

As a sharp contrast to life-curves in which the youthful stages are prolonged take the case of the Mound-Birds of Borneo, where the whole of the chick period has been telescoped. The eggs are laid in heaps of fermenting vegetation, or are sometimes buried near hot springs; and there is nothing of the nature of brooding or watchful care. When the young bird scrambles out of the egg-shell it instinctively continues its struggles and frees itself from the mound. Observers tell us that if it should become thoroughly exhausted in the process and cease to struggle, it cannot resume its efforts and must perish miserably. This is a common feature in instinctive behaviour, that interruptions are apt to prove fatal. In most cases, however, the young Mound Bird succeeds, and an hour after hatching it is fending for itself in the scrub. In some cases it flies on the day of its hatching! It passes out of the egg into the tasks of everyday

life in one great bound, skipping the whole juvenile period. What a contrast between this and the prolonged youth of the elephant, for the young giant sometimes remains for ten years beside its mother. The elephant is, of course, a slow-growing and slowly reproducing type, which may reach an age of a hundred years, but even then the youthful period is long in proportion. In many mammals there is not only prolonged youth but prolonged maturity; and most come to a violent end without any visible trace of senescence in the tissues.

A cockchafer may have a larval period of four years: contrast that with the exceedingly rapid larval development of types like bluebottles, which do not require more than three days. Many nesting birds, e.g. the Golden Eagle, have a prolonged nurture in the cradle; what a contrast to birds of, say, the plover type, with little more than an apology for a nest, for in these types the newly hatched young creature is extraordinarily precocious, more fully finished than a chick, active and at home almost immediately after hatching.

These instances must serve to illustrate our thesis that the life-histories of different animals differ in the *tempo* of the various parts of the general life-curve. For the plant world the same holds true, for not only are there annual, biennial, perennial, century plants, and so on, but there are instances of prolonged leafing and long-delayed flowering, of withering after seed-scattering, and of persistent nutritive vigour unaffected by reproduction. The flower of the common garden Day-Lily (Hemerocallis) literally deserves that old name, while a single flower of a Lady's Slipper orchid (Cypripedium) may last three months.

FACTORS DETERMINING LIFE'S TRAJECTORY.—The factors that alter the average or normal form of the life-curve may be grouped as environmental, functional, or organismal.

(*a*) ENVIRONMENTAL.—In cold waters the rate of protein-metabolism is slowed, and therefore, since there is less chromatin produced, there are fewer cell-divisions in a given time. The eggs of the salmon in the cold rivers may take three months to hatch. In cold surroundings the duration of life tends to be prolonged; there are thus more generations living at the same time; hence the plankton is denser in northern seas than at the Equator. There are indications that life is very slow in the eternal winter of the great abysses; in tropical water it is often hurried. Stimulating food hastens development, as is seen in maggots amid the flesh and in some internal parasites. Linnæus remarked that a flesh-fly and its progeny may devour the carcase of an ox more rapidly than a lion can. But uncongenial food may retard development, and Planarian worms misfed may have offspring that are "born old". The conditions of

illumination have very diverse effects, sometimes retarding and sometimes accelerating growth.

(*b*) FUNCTIONAL.—The habits of the animal may influence the life-curve, and this finds a familiar parallel in the way man ages or keeps young according to his tasks and ploys. A strenuous roving creature like the otter, with its several homes and frequent journeys between, remains singularly young, and even playful, throughout its adult life. Perhaps the youthfulness and joyousness of most birds may be in part correlated with the migratory habit, with its stimulating changes and its double summer in the year. When adult life in insects is entirely devoted to reproduction—and some could not open their mouth even if they would—the period of maturity is bound to be short.

(*c*) ORGANISMAL.—The quality of being long-lived is sometimes demonstrably hereditary in human lineage, just like the similarly subtle quality of fecundity. So the shape of life's trajectory may be correlated with the inborn constitution, and the lengthening out (or the shortening down) of different arcs in the curve may be correlated with time-variations in the activity of the endocrinal glands—though these time-variations have also to be accounted for in due course. As the hormone-output of the supra-renal gland is intimately correlated with emotional disturbances, such as anger and fear, it is not so far-fetched as it may seem to ask whether psychological, as well as physiological, factors do not operate in altering the life-curve. As was wisely said of old time, "A merry heart is a continual feast", and "A merry heart is the life of the flesh".

It is truistic to say that the form of the life-curve will tend to be congruent with the organic constitution, but it is possible to give the idea some concreteness. Thus a very steady growing, without the usual limit of growth, is seen in many fishes and reptiles, which live a markedly anabolic life with abundant nutrition, with resting habits, and with rather cold-blooded reproductivity. The most prolonged maturity known among living creatures is that of the "Big Trees" or Sequoias, some of which have lived for 3,000 years, and they are obviously quietly-living, often resting, highly anabolic types, with an enormous income in relation to their expenditure. This holds for some centenarian animals as well, such as elephants and giant tortoises, but we are by no means denying that the same result may be attained along other lines, as the strenuous prolonged maturity of the eagle well shows.

But while we regard this physiological reading of the life-curve as primary, even though it be still tentative, it requires to be supplemented by an attempt to interpret the diverse forms as each and all *adaptive* to particular circumstances. There is an ecological significance—and, more generally, a survival value in all the differences of time and tune.

This aspect of the problem is illustrated in the section on larvæ; a couple of illustrations must here suffice. The foal is much better equipped at birth than the calf; it has, so to speak, a shorter infancy; and this is adaptive to their differences in habit. For in natural conditions the cow hides her calf in the thicket, whereas the foal has to stumble along after its nomadic mother. Correlated with this is the fact that the calf enjoys a prolonged meal, sucking to repletion, while the foal is suckled hastily, but at frequent intervals. Hence, too, the cow's udder is so large, and the mare's so small.

The prolongation of ante-natal life and the suppression of youthful stages must often have a high protective value, as is strikingly illustrated by Peripatus. But another aspect is prominent in the prolonged gestation of many mammals. As Robert Chambers pointed out in his *Vestiges of Creation*, it may admit of the development of a larger brain before the time of critical testing begins. Thus the centres of the cerebral cortex in particular may reach a high grade of organisation before they begin to be flooded with sensory news from the outer world or taxed by the requirements for control—whether of eye-adjustment, of manipulative dexterity, or of agile movements in general.

But let the unifying idea stand out clearly that it is characteristic of life-histories to show an ascending and descending curve, and that different arcs on this curve or trajectory of life are shortened or elongated adaptively in relation to particular circumstances of life. Human life shows much the same series of phases upon its life-curve as those mentioned at the outset; but of these we have spoken briefly elsewhere.

ALTERNATION OF GENERATIONS

We see that the life-history of an organism, whether plant or animal, is to be thought of as an ascending and descending curve, with a summit that may be a peak or a plateau. From the *vita minima* of the tender embryo the organism climbs through insurgent youth to maturity; and thence, sooner or later, it begins to sink towards the *vita minima* of senescence. But the variations on this general theme are many, and the trajectory of life must be thought of as elastic in relation to seasons and circumstances. As noticed above, there may be a long or a short embryonic development, a long or a short youth, a long or a short adolescence, and similarly for maturity and ageing. The elephant lives for towards two years before it is born, and may not be mature till it is 40 years old. What a contrast to the entire life of a summer bee, which may be all over in a couple of months or less. The eel has a longish life of growing, say half a dozen years; but it seems always

to die after spawning, so that the ageing part of its life-curve is almost like a perpendicular. Lord Avebury kept two queen-ants of different species for nine and fifteen years respectively; what a contrast to the life-curve of one of the Mayflies or Ephemerids, which is said to have an adult life of a single hour!

This idea of the adjustability of the length of different arcs on the life-curve points on to the interpolation of larval stages. Out of the egg of a cockroach, locust, earwig, or spring-tail, there emerges what is almost a miniature of the adult; and there can be little doubt that this is the primitive kind of life-history among insects.

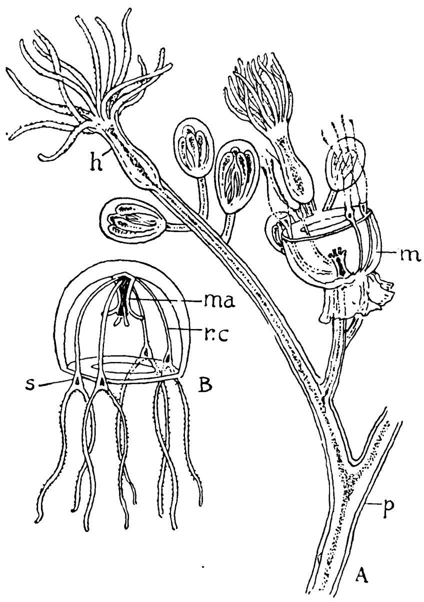


FIG. 125.

Alternation of Generations. After Allman. A, a magnified portion of an asexual hydroid or zoophyte colony; *h*, an ordinary nutritive polyp or hydranth; *m*, an almost complete reproductive bud or medusoid; *p*, external investment or perisarc. B, a liberated sexual swimming bell or medusoid; *ma*, manubrium or mouth-tube; *nc*, radial nutritive canal; *s*, sense-organ; tentacles hanging down.

But, as everyone knows, all the higher insects have their life-history complicated by the occurrence of larvæ, such as caterpillars and grubs; and it seems that these larval phases have been secondarily interpolated in adaptation to seasons and circumstances. The winged adults are more or less specialised for reproduction; the larval stages are specialised for nutrition and growth. In some cases the adult insects do not feed at all; and with one exception (Mayflies) there is no moulting after the winged stage is reached—which is another advantage of the larval parenthesis.

From indirect or circuitous development, with larval stages and metamorphosis, it is but a step, though a large one, to Alternation

of Generations, which is of wide occurrence both among plants and animals. Many of the fixed, vegetative, plant-like, asexual zoophytes or hydroid colonies, which grow on stones and shells and seaweeds in shallow shore-waters, bud off swimming-bells or medusoids in the summer months. These beautiful transparent bells swim in the open waters, and are sexual. Their fertilised eggs develop into embryos, which become free larvæ, which soon settle down as polyps, and form new arborescent colonies by budding. This is typical alternation of generations, of the type that is technically called metagenesis. The asexual hydroids bud off sexual medusoids, whose fertilised egg-cells give rise to hydroids again (Fig. 125).

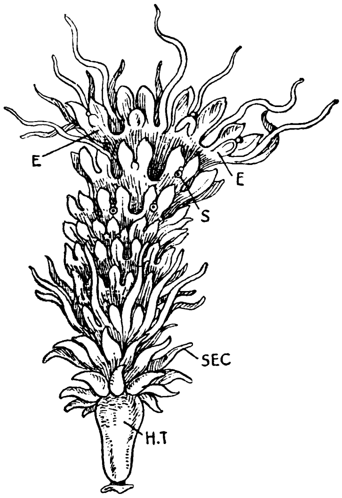


FIG. 126.

The Strobila Phase in the Life-History of a Jellyfish (Aurelia). It consists of a vertical series of horizontal buds, often compared to a pile of saucers, each of which in turn is separated off as an ephyra or young jellyfish. E, uppermost and oldest scyphomedusa or disc; S, a sense-organ in one of the bifid marginal lobes; SEC, second youngest disc; HT, hydra-tuba, the polyp-like individual from which the discs are successively budded off.

To take a superficially very different case, the common medusa or jellyfish (Aurelia) gives rise to egg-cells or sperm-cells, and the fertilised egg-cell develops into a free-swimming larva. This settles as a polyp-like form, the hydra-tuba, and this, by a kind of budding, gives origin to little saucer-like discs which grow into medusæ. In this case the sequence is: Medusa, sex-cells, free larva, fixed asexual polyp, budding, young medusa (Fig. 126).

Now it is an interesting fact that some medusæ, like the luminescent Pelagia, common on the high seas, give rise sexually to other medusæ, without the interpolation of a fixed polypoid stage. Similarly there are many swimming-bells or medusoids (anatomically very different from medusæ) whose fertilised egg-cells also give

rise directly to other medusoids without the interpolation of a fixed polypoid or hydroid stage. This is part of the argument that leads to the conclusion that the ancestors of both medusoids and medusæ were free-swimmers; and that the fixed, vegetative, asexual phase has been interpolated secondarily. Yet some naturalists read the story in a precisely opposite way, and regard the fixed stages as the more primitive.

This seems to us improbable; but the uncertainty does not affect our general suggestion, that alternation of generations is to be regarded as a special outcome of the plasticity of particular arcs in the life-curve, and of the tendency to interpolate larval stages to meet certain difficulties. It should also be noted that larvæ some-

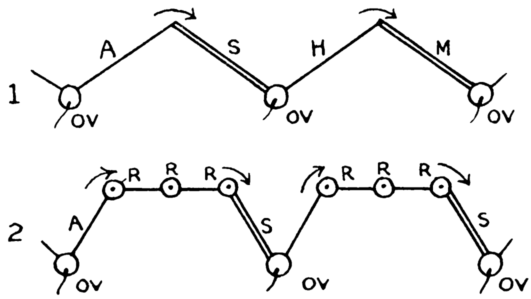


FIG. 127.

Diagram of Alternation of Generations. 1. In a Hydromedusoid life-history. A fertilised ovum (OV) develops into a free-swimming larva which settles down and becomes a polyp, which asexually buds off (A) a hydroid colony. From this by budding are produced free-swimming medusoids (S), which become males and females, from which arise the fertilised ova, starting a fresh cycle. 2. In a liver-fluke life-history. A fertilised ovum (OV) develops into an asexual larva, which produces by means of spore-cells (R) a succession of asexual larvæ. But eventually the last larval form develops into a sexual fluke (S), producing self-fertilised ova.

times become precociously reproductive—a peculiarity also pointing the way to alternation of generations.

From a sheep infected with liver-rot the microscopic developing embryos of the liver-fluke drop on to the wet pasture. Out of the eggshell comes a ciliated free-swimming larva which may find its way into a small water-snail. There it gives rise by means of unfertilised egg-cells, like spore-cells, to another kind of larva (redia), which immediately proceeds to do the same. Eventually there are formed little tailed larval flukes (cercariæ), which leave the snail and the water, and encyst on blades of grass. If one of these minute white specks be swallowed by a grazing sheep, the young creature passes from the food-canal to the liver, and there grows rapidly into the hermaphrodite fluke. In this case the rediæ and cercariæ are produced not asexually, in the strict sense, but from germ-cells which do not require fertilisation and might be called spores.

This leads us to what is familiar in ferns and their allies—the alternation between an inconspicuous male-and-female prothallus,

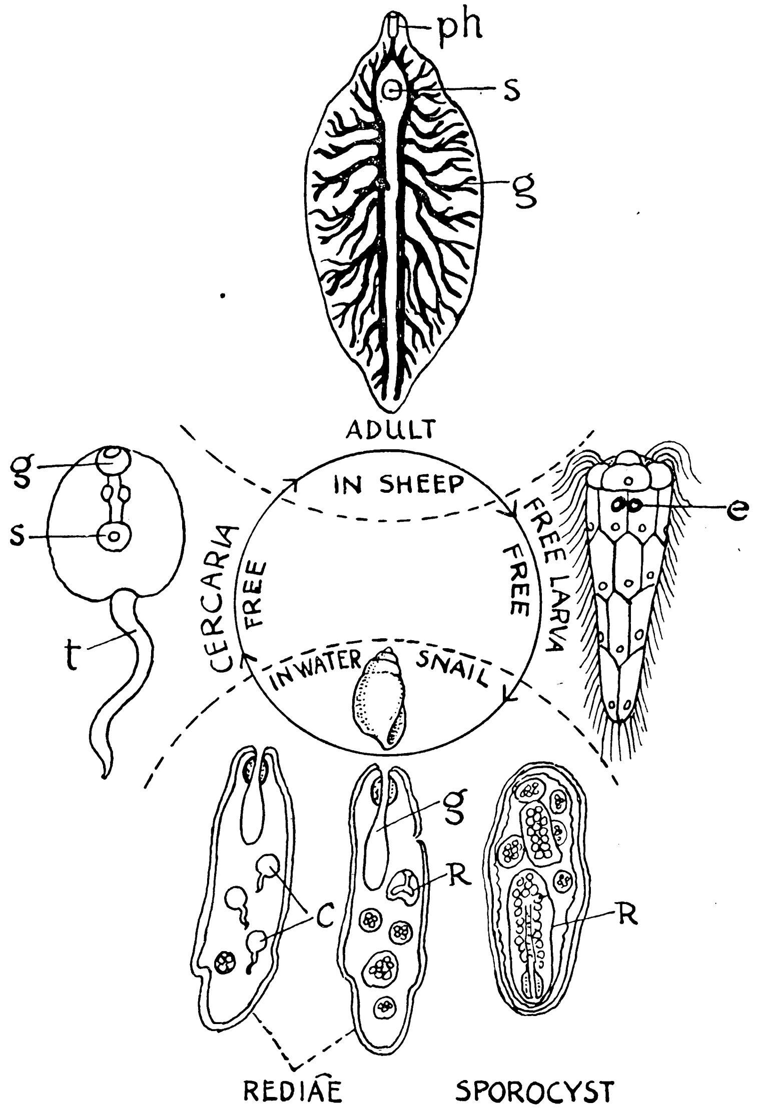


FIG. 128.

The Four Chapters in the Life-History of a Liver-Fluke. (1) The adult, natural size, with its pharynx (*ph*), adhesive sucker (*s*), and much-branched gut (*g*). (2) The much magnified free-swimming ciliated larva or miracidium, with its two eye-spots (*e*). (3) The sporocyst and redia stages. R, redia developing inside a sporocyst or another redia. A simple food-canal (*g*) in a redia. C, young cercariæ inside final generation of rediæ. (4) Much magnified free cercaria, showing (*g*) the beginning of the gut, (*s*) the adhesive sucker, and (*t*) the locomotor tail.

a little green disc found in wet, shady places, and the conspicuous vegetative spore-producing fern-plant with its beautiful fronds.

Thus when spores fall from the brown sporangia on the under side of the fern-fronds they develop into prothalli; and from the fertilised egg-cell of a prothallus there develops the ordinary fern-plant. There is an obvious advantage in having a vigorous sporophyte (what we call "a fern"), with its multitudes of spores which do not require water for their production and propagation, in striking contrast to the small delicate prothallus (or gametophyte), whose egg-cells cannot be fertilised without the presence of external water in which the male cells swim.

The plasticity and adaptability which we are seeking to emphasise is illustrated by the occasional production of buds, both on the fern and on the prothallus; and also by the occasional short-cuts, of apogamy and apospory, as when a fern-plant springs directly from the prothallus and not from its fertilised egg-cell, or

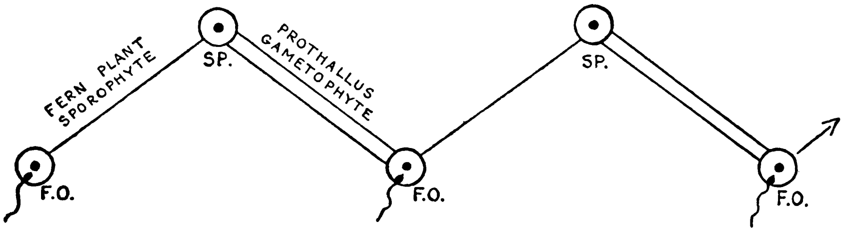


FIG. 129.

Alternation of Generations in Fern Plant. FO, the fertilised ovum, which develops into the asexual sporophyte or ordinary fern plant. A spore (SP) gives rise to the sexual prothallus.

when a prothallus arises directly on the fern-frond and not from a spore.

An alternation of parthenogenetic development (from an unfertilised egg-cell) and ordinary spermic development (from a fertilised egg-cell) is well illustrated among greenflies, water-fleas, wheel-animalcules, threadworms, and flukes; and this kind of alternation is technically called heterogenesis, in contrast to the alternation of asexual and sexual generations, as in hydroids and medusoids (metagenesis). But what happens in ferns and flukes is somewhat between the two types of alternation.

The general idea may be defined by saying that alternation of generations is the alternate occurrence, in one life-history, of two or more different forms differently produced. We do not wish to get into a tangle, but there is a difficult question that must be asked, though it cannot be at present answered. In flowering plants there is an indubitable alternation of generations, which the genius of Hofmeister disclosed, though it is extraordinarily well concealed or masked. Should this not lead zoologists to be a little more open-minded and inquisitive in regard to the sporadic suggestion that

there may be a masked alternation of generations in the life-history of certain animal types like starfishes, butterflies, and even armadillos?

LIFE-HISTORIES OF PLANTS

In higher plants we are familiar with the ascending and descending curve of life, so emphatic in annuals—sprouting, developing, leafing, growing, flowering, fruiting, seeding, withering, and dying. And even when the plant lives on for many years there are on the main

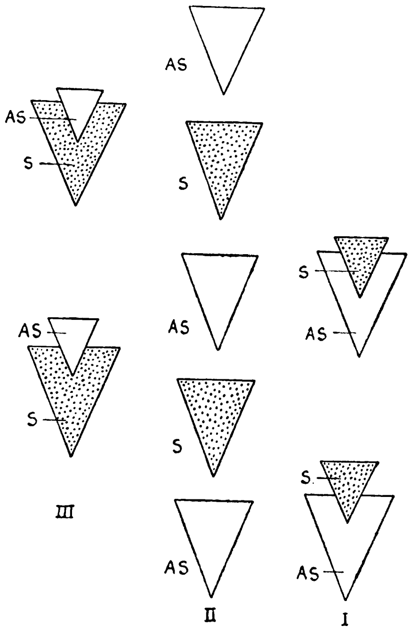


FIG. 130.

Diagrammatic Representation of Alternation of Generations. AS, asexual, and S, sexual. II shows a well-defined alternation of separate individuals, asexual and sexual. In I the sexual (S) is becoming increasingly subordinated to the asexual (AS), as in Flowering Plants. In III the asexual (AS) is more and more subordinated to the sexual (S), as in Mosses.

curve or trajectory the minor ups and downs of leafing and flowering, fruiting and seeding, determined by the seasons.

Just as among animals there is sometimes a very unusual form of life-curve. This may be illustrated by the Century Plant (*Agave americana*) which is vegetative for a long stretch of years, sometimes for a whole human generation, and then suddenly bursts into a gorgeous inflorescence and dies! In the basal rosette of large leaves there is an accumulation of nutritive reserves and water; on the strength of this a gigantic flower-stalk rises many feet into the air, and as it grows and blossoms the basal leaves fall back limp and moribund. After the ripening of the fruit, the Century Plant,

exhausted by its exuberant reproductive expenditure, rapidly withers away.

Among the Algæ and Fungi (the Thallophytes) there are many very striking life-histories, but it seems for our present purpose more instructive to begin at a higher level—with the Liverworts and Mosses (the Bryophytes). Here we find a well-established alternation of generations of a type rather different from that which sometimes occurs among Thallophytes and closely akin to that which is found in the higher Ferns and Horsetails (Pteridophytes).

We have defined alternation of generations as the alternate occurrence in one life-history of two different forms differently produced. The one form produces spores, germ-cells requiring no fertilisation, and is called a *sporophyte*; the other form produces egg-cells and sperm-cells, and is called a *gametophyte*. In the cells of the sporophyte the number of nuclear chromosomes is twice that found in the cells of the gametophyte. In technical language the sporophyte has the diploid ($2n$) number, and the gametophyte the haploid (n) number. A meiotic or reducing division occurs in the formation of the spores. The diploid number is restored in the fertilisation of the egg-cell by the sperm-cell.

LIVERWORTS.—On moist soil or rocks there are often extensive growths of small flat plants or Hepaticæ, which are interesting as the probable representatives of the earliest terrestrial vegetation. Air-pores on the upper surface of the prostrate thallus lead into air-chambers into which there project numerous short filaments with chlorophyll corpuscles—the seat of photosynthesis. In typical forms, like the common Marchantia, the under surface is colourless and gives off absorbing root-hairs or rhizoids. The upper surface often shows little cups in which minute buds or gemmæ are produced, and if these are washed away they develop into new gametophytes.

From the upper surface of the Marchantia thallus delicate stalks rise, bearing a disc or receptacle on their summit. These are the male and female sex organs, and the two kinds may occur on one gametophyte as in Riccia or, as in Marchantia, on two separate plants. The male receptacle bears flask-shaped cavities on its upper surface, and in each of these there is a somewhat club-shaped male organ or antheridium. Within a protective sheath there are sperm-mother-cells which produce spermatozoa or antherozoids. Each of these is a minute spirally twisted cell, ending in two motile cilia. Moving in the water, which is usually abundant about the liverworts, a spermatozoon finds an egg-cell and fertilises it. The egg-cell is formed at the base of a flask-shaped archegonium, which consists of a protective outer wall and internal germ-cells. The lowest of these

cells is the ovum; the others, often eight in number, are auxiliary "canal-cells" which break down and leave a path by which a spermatozoon may enter. In Marchantia these female organs or archegonia occur in the notches of a star-shaped stalked receptacle, whose shape suggests a fairy parasol. By inequality in the growth of the disc the archegonia are bent round to the surface next the thallus, and there they hang with the mouth of the flask downwards.

When the egg-cell is fertilised, it develops into a small sporophyte, which is anchored in the gametophyte and bears a rounded spore-capsule on the tip of a delicate stalk or seta. The tissue inside the capsule makes spores, but it also forms elongated cells with a spiral thickening (elaters), which are very hygroscopic and by their twisting about when moistened help to scatter the spores.

As might be expected, there are several grades among the Liverworts and numerous differences in detail; but the general sequence of the life-history is the same in all, and may be thus represented in schema:

Spores ⟶ Sexual Gametophytes (Haploid) ⟶ Egg-cells and sperm-cells ⟶ Sporophytes (Diploid) ⟶ Spores

MOSSES.—The large group of Musci is allied to the Liverworts and probably evolved from some of their progressive types among the Anthocerotales or the Jungermannias. They are represented all over the world except in the sea, and they are very successful in all zones. Low-growing, unless epiphytic, very easily multiplied asexually, able to resist both frost and drought, mosses have taken a strong grip of the earth, and are rich in species. They afford shelter to a multitude of minute animals, such as Rotifers and Mites. But we have here to do with their life-history.

Most characteristic perhaps is the sporophyte which grows up from the fertilised egg-cell in the female organ of the familiar moss-plant. On the tip of a slender stalk there is a very complex little capsule, containing spore-forming tissue; and outside the capsule for a time there is a hood or cap, called the calyptra. The top of the capsule bears a lid or "operculum" which eventually slips off, and just below the lid there is a beautiful ring of little tooth-like projections, forming the "peristome". In the true mosses no small part of the capsule consists of green photosynthetic cells; but the upper part is given over to spore formation. Perhaps the green tissue is a hint of a possible independence of the Sporophyte, but this is never achieved in Bryophytes.

A spore falling on the moist soil develops into a branching filament (the protonema), which is the equivalent of the thallus of a liverwort. From the filament there grow slender branches, some-

times erect, sometimes sprawling, and among terminal clusters of very simple leaves, usually one cell thick, there are developed the sex organs. Both archegonia and antheridia may occur in the same leaf cluster, or they may be in separate clusters. An antheridium is like a simple club; it makes the sperm-mother-cells and liberates them in a little blob, thereafter closing up again. The sperm-mother-cells give rise to spermatozoa with two cilia. When the sexual branch is erect and out of the moisture, it may be difficult for the spermatozoon to find any medium in which to swim. This will hinder fertilisation, and many mosses are chiefly multiplied asexually—by breakage, by budding, and in other ways. The archegonium is a minute elongated flask, with an egg-cell near the base and disintegrating canal cells in the neck, down which a spermatozoon may make its way. From the fertilised egg-cell there develops the sporophyte. Thus the sequence is:

Spore	⟶	Protonema with sexual branches bearing sex-organs	⟶	Fertilised egg-cell	⟶	Dependent sporophyte, with spore capsule	⟶	Spore

PTERIDOPHYTES.—One of the difficulties in giving even an outline account of the evolution of plants is the gap between the mosses and the ferns, or more technically, between the Bryophytes and the Pteridophytes. Thus D. H. Scott, after a long discussion, remarks that "there is no evidence, fossil or otherwise, for the evolution of the higher Cryptogams from Bryophyta or any plant at all like them. It is more probable that they came direct from plants which were rather of the nature of Algæ; this view, however, is a pure hypothesis. . . ." (*Evolution of Plants*, p. 228.)

In mosses the sporophyte is leafless and dependent on the gametophyte, while in ferns it is a leafy, vascular, well-rooted plant, quite independent of the sexual phase. This is a very striking contrast, which raises difficult problems.

LYCOPODS OR CLUB MOSSES.—In the great forests of Carboniferous times there was an abundant representation of Lycopods, and some of them, called Lepidodendrons, attained the dimensions of huge trees. Their stock can be traced back to the Devonian, when they flourished along with ferns and the like.

Nowadays there are only four genera of Lycopods: Lycopodium, Phylloglossum, Selaginella, and Isoëtes. The common "stag's-horn moss" of the moors is a Lycopodium, but it has no affinity with mosses. In Lycopodium the wiry stem is forked and covered with small leaves; in Selaginella, which is common in greenhouses, the stem is more delicate, and the life-history, as we shall see, is

strikingly different. The aberrant Isoëtes or quillwort is aquatic or amphibious, with stunted stems and long quill-like leaves. We shall begin with the life-history of a typical Lycopodium.

The simplest Lycopodium sporophyte is a leafy stem, with every leaf a sporophyll, that is to say, bearing a sporangium on its upper surface. But in other species there is a division of labour between the lower foliage leaves and the upper sporophylls, which are closely clustered into a "strobila". In the centre of the stem in the young stages and simpler types there is a cylinder or stele, consisting of a core of wood or xylem (water-conducting tissue) and a sheath of bast or phloem (food-conducting tissue). This is the simplest form of vascular system. The central cylinder gives origin to branches or leaf-traces which pass out into the veins of the leaves.

A spore falling from a sporangium gives rise to the gametophyte, which typically shows a complex subterranean tuberous body (the *primary tubercle*), and an above-ground green portion (the *crown*), which bears the sex organs. The tuberous part always contains a partner fungus (see Mycorhiza); but this region is suppressed in some epiphytic Lycopodiums, whose gametophyte is therefore altogether aërial, though not always green! In other species, the crown is rudimentary or absent, and the sex organs arise directly from the tuberous body. These are interesting alternatives, showing a suppression of the rooting region in one case and of the photosynthetic green shoot in the other.

The sex organs consist of antheridia and archegonia imbedded in the upper surface of the crown. The sperm-cells are unusual among Pteridophytes in being biciliate as in Bryophytes. After fertilisation the egg-cell divides into a suspensor cell (very characteristic of seed plants) and an embryo-cell. The latter divides into four unequal quadrants, two of which form a foot (as among Bryophytes) which absorbs food for a time from the gametophyte, while the two others give rise to the stem and the first leaf (plus root) respectively.

Among the liverworts, or, as some would say, beside the liverworts, there is a peculiar group, whose type is Anthoceros. The most outstanding peculiarities are that the sporophyte is beginning to be green, which spells independence; that the spore-making tissue is beginning to be divided into compartments, anticipatory of sporangia; and that there is a hint of division of labour between spore-making and non-reproductive tissue. Bower has pointed out that if the green tissue increased in proportion, and gave off minute extensions, each with a spore-making patch at its base, there might arise something like the strobila of a Lycopod; and we have already mentioned that there are among species of Lycopodium various gradations from a sporophyte with sporophylls only and one with a considerable development of foliage leaves as well.

The schema summing up the Lycopodium life-history is as follows:

Spore →	Gametophyte →	Fertilised →	Embryo Sporo- →	Sporangia
	inconspicuous, usually in part subterranean, with antheridia and archegonia aërial	egg-cell	phyte, for a time dependent by means of a "foot" on the gametophyte	

The Australasian Phylloglossum closely resembles Lycopodium in its gametophyte (a subterranean tuberous portion bearing a green aërial crown with sex organs), but its sporophyte is arrested at a stage corresponding to the very young stage in some Lycopods, and becomes a tuberous stem with a cluster of small leaves and a stalked strobila.

SELAGINELLA.—This is a very successful genus with about 500 species, mostly tropical. It can be traced back to the Carboniferous Period, when there were delicate little forms not very different from many of those now living, but in striking contrast to the giant Lepidodendron trees of the Carboniferous. Then, as now, the Selaginellas produced two kinds of spores, macrospores and microspores; and this gives them a peculiar interest, since it is the first hint of the contrast so marked in Flowering Plants between pollen-grain and embryo-sac.

The Selaginella sporophyte is a branching leafy stem, with a gradation between foliage leaves and sporophylls, but the sporangia begin *on the stem* just above the origin of the sporophyll. Near the base of each leaf there is a minute flap or ligule, prominent during development and afterwards inconspicuous, which is a good instance of a minute structural feature that is quite constant. It is present in all Selaginellas and absent from all Lycopodiums.

All the sporangia begin in the same way, but they soon diverge in development. In some, the microsporangia, usually in the majority, the mother-cells form many microspores, four from each mother-cell. In others, the megasporangia, only one mother-cell comes to anything, and it develops into a tetrad of four large megaspores. In a word, the Selaginellas are heterosporous, whereas Lycopodium is homosporous. Moreover, when a microspore is shed it develops into a male gametophyte, which is so much telescoped that it never gets free from the spore-wall. The spore divides into (*a*) a single vegetative cell, all that there is to represent the vegetative body of the gametophyte, and (*b*) a reproductive cell which forms an antheridium, eventually giving rise to minute biciliate sperm-cells. It gets carried to a megasporangium, within which a megaspore develops into a female gametophyte. This shows two distinct regions, vege-

tative and reproductive, and the latter bears archegonia. A male gametophyte, falling or wind-borne, lands among megasporangia; it bursts from the microspore wall and sperms are liberated. One of these enters an archegonium and fertilises an egg-cell. This develops into a nutritive suspensor and an embryo with foot and leaves, shoot and root. This embryo gets free on the surface of the strobilus, very much as if it were a seed sprouting, and by and by the whole strobilus falls off. The schema is:

(A) Microspore ⟶	Reduced male gametophyte, within microspore, with antheridium ⟶	Biciliate sperm-cell fertilises ↓		
(B) Megaspore ⟶	Reduced female gametophyte, within megaspore, with archegonia ⟶	Egg-cell within megaspore ⟶	Embryo sporophyte with microsporangia and megasporangia	

ISOËTES.—In the aquatic or amphibious quillworts of this aberrant genus, the stem is extremely short, the leaves are somewhat grass-like, and each has a basal sporangium. This diverges in the course of development to become a micro- or a mega-sporangium. The spores escape by a decay of the sporange wall and the microspore forms an interestingly reduced male gametophyte, which points the way to seed plants. It consists of a single vegetative cell and an antheridium with only four sperm-mother-cells (in seed plants further reduced to two). The sperms are large, coiled, and multiciliate as in ferns and horsetails. The female gametophyte, telescoped into the megaspore, does not protrude and is accessible only through a crack. From the fertilised egg-cell the sporophyte develops, and shows a striking likeness to the embryo of Monocotyledons.

HORSETAILS.—The historian of the fern-like plants or Pteridophytes must take account of two very small living plants, Psilotum and Tmesipteris, which are milestones in their way, and of the extinct Carboniferous Sphenophylls; but in our merely illustrative survey we must now pass to the Horsetails or Equisetaceæ, a great group in the past, rising to the height of a hundred feet in the Carboniferous, but now represented by a single genus, Equisetum, and mostly small.

They are familiar plants in their sporophyte phase, marked by subterranean axis, jointed aërial stem, whorled green branches, reduced scale-like leaves, and sporangia in cone-like fructifications.

This cone bears stalked sporangia, but apparently no sporophylls. Modern types are homosporous, and the outermost layer of the spore cracks into two peculiar coiled bands, which unwind and get entangled with their neighbours. There are usually separate male and female gametophytes, the latter the larger, forming small green branching thalli on the surface of the soil. The egg-cell in the archegonium is fertilised by a large biciliate sperm-cell, produced in an antheridium; and the result is the familiar sporophyte. The schema runs:

Spores	⟶	Above-ground green gametophyte usually diœcious	⟶	Fertilised egg-cell	⟶	Sporophyte with sporangia on a sort of cone

With interesting resemblances to the Lycopods, but oftenest ranked with Ferns, are the aberrant Adder's Tongue (Ophioglossum) and Moonwort (Botrychium), in both of which the "fertile spike" of sporangia is very distinct from the vegetative part of the sporophyte.

ORDINARY FERNS.—The highly successful fern group goes back to the Devonian, and is represented by 3,000 or more living species. They are probably the only plants whose "alternation of generations" has been noticed by casual observers, for it is very well known that what grows from the sown spore of a fern is a very different kind of plant, a little, flat, green disc on the surface of the damp soil. From this the beginning of the asexual spore-bearing plant can often be seen growing.

From a spreading underground stem, the leaves or fronds arise, sometimes, as in Bracken and Royal Ferns, to the height of a man. On the back of a leaf are numerous sporangia, sometimes with an enormous total, though with a small individual production of spores. On a damp substratum a spore develops, through a filamentous phase, into a green prothallus, with white rhizoids below and also the sex organs. The antheridia are usually on the older ventral part among the rhizoids; the archegonia are later of appearing, and are situated near the apical notch. The large sperm has numerous cilia, and it is interesting to find that its nucleus is usually the only part that actually enters the egg-cell. From the fertilised ovum in the archegonium the familiar sporophyte develops. The schema is:

Spore	⟶	Prothallus with antheridia and archegonia	⟶	Fertilised egg-cell	⟶	Sporophyte with sporangia, usually homosporous, heterosporous in the water-ferns

Sometimes a sporophyte develops from a prothallus without there being any fertilisation. This "apogamy" may imply either a

parthenogenetic ovum or a vegetative multiplication on the part of the prothallus. An apogamous sporophyte has the haploid number of chromosomes.

But a gametophyte may be produced from a sporophyte without any spore, either from an arrested sporangium or from vegetative tissue. An aposporous gametophyte has the diploid number of chromosomes. Fact and theory agree!

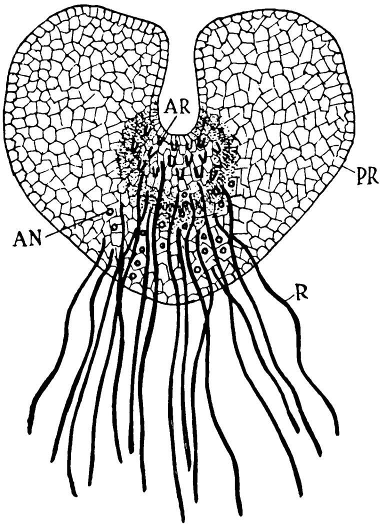


FIG. 131.

Prothallus or Sexual Generation of a Fern (Aspidium). Under surface. After Strasburger. AR, archegonia or female reproductive organs; AN, antheridia or male reproductive organs; PR, lobed prothallus about the size of half a threepenny bit; R, rhizoids.

SEED-PLANTS OR SPERMATOPHYTES.—These are the higher plants, often called Phanerogams or Flowering Plants in contrast to the Cryptogams or Flowerless Plants. The scientific emphasis should certainly be on the *seed*, for that was the main step in evolution. It implies that the embryo develops for some time within a large megasporangium (the ovule), in dependence on the parent plant. It is usual to divide the seed-plants into the *Gymnosperms*, like pines, with the seeds exposed, and the *Angiosperms*, like ordinary Flowering Plants, with the seeds enclosed in a case, badly called the ovary.

A detailed comparison of a heterosporous Pteridophyte with a typical Flowering Plant is given on the next page.

While many puzzles remain, such as the contrasted sporophytes of moss and fern, or the origin of the seed, or the peculiar endosperm of ordinary Flowering Plants, there is no doubt that the recognition of alternation of generations from Bryophyte (or earlier) to Flowering Plants, in which it is so well disguised, has unified and elucidated

(1) The green sporophyte, say of Selaginella, with foliage leaves and sporophylls.	(1) An ordinary green Flowering Plant with foliage leaves and with two kinds of sporophylls, the stamens and carpels.
(2) A microsporangium.	(2) A part of the anther of a stamen, a pollen-tract, equivalent to two coalesced micro-sporangia.
(3) A microspore.	(3) A pollen-grain, one of four reduced "tetrads" formed from a mother-pollen-cell.
(4) The male gametophyte greatly reduced.	(4) The generative cell (dividing into two male nuclei) and the pollen-tube nucleus.
(5) The megasporophyll.	(5) The carpel.
(6) The megasporangium.	(6) The ovule, or more strictly the nucellus of the ovule. The origin of the ovule may be either foliar or cauline, within the shelter of the carpel.
(7) The megaspore.	(7) The embryo-sac, which is usually the sole survivor of four tetrads, formed by reduction division from a single sporogonous cell.
(8) The female gametophyte.	(8) Eight nuclei formed by three divisions of the embryo-sac. After the first division the nuclei pass to opposite poles; at the micropylar pole, where the pollen-tube enters, four nuclei are formed, and similarly at the other end. A nucleus from each group passes to the centre, and the two fuse to form the primary "endosperm nucleus" with a nutritive function. Of the three nuclei left at the micropylar end, one forms the ovum, the others are called synergids or helpers. The three antipodal nuclei may come to nothing or may form nutritive cells.
(9) Fertilisation of egg-cell by sperm-cell.	(9) The intimate union of a generative cell or nucleus from the pollen-tube with the egg-cell or its nucleus.

(9*a*) But in Angiosperms the other generative nucleus from the pollen-tube fuses with the endosperm-nucleus, which has been formed from the fusion of a micropylar and an antipodal nucleus. The outcome of the triple fusion is a sort of twin of the embryo-sporophyte, and forms a nutritive tissue filling up the embryo-sac. This puzzling phenomenon is peculiar to Angiosperms; the endosperm of Gymnosperms is different.

(10) The embryo-sporophyte.	(10) The embryo-sporophyte inside the seed, less the peculiar endosperm (9*a*) of Angiosperms.

the life-histories of plants in a very remarkable way. This was mainly due to the genius of Wilhelm Hofmeister (1824–1877), who laid the foundations of his comparative embryology in the spare time of his everyday work as a music-seller. What he added after he became a Professor was merely extension and corroboration.

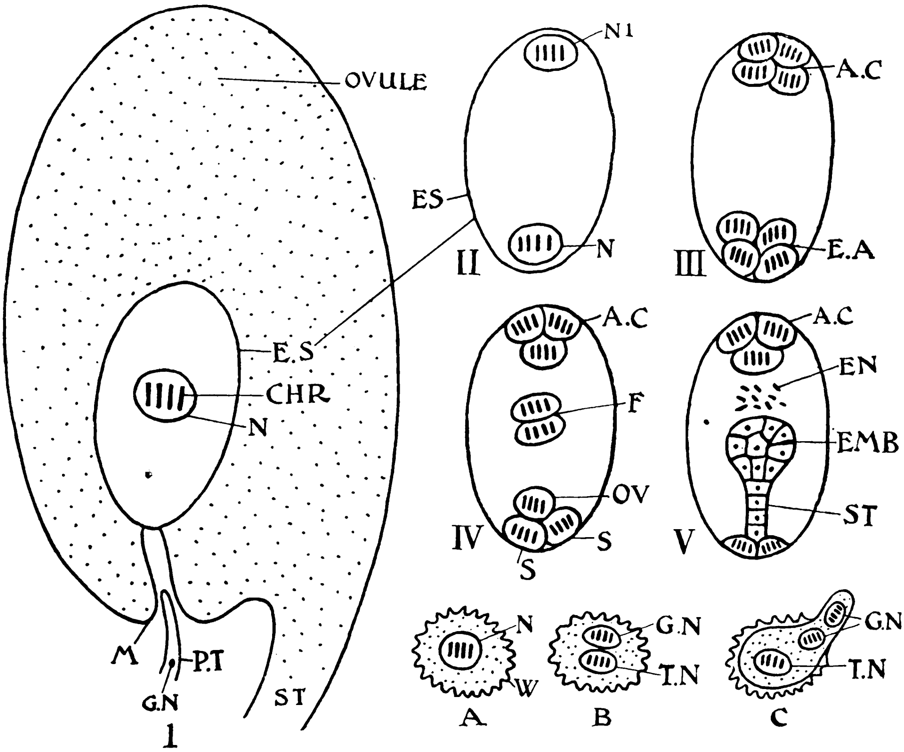


FIG. 132.

Fertilisation and Early Development in Flowering Plants. I. Section of ovule; ST, stalk; N, nucleus of embryo-sac (ES), with four chromosomes (CHR); M, micropyle, through which there enters a pollen-tube (PT), containing the generative nucleus (GN). II. The embryo-sac (ES) further enlarged, with the nucleus divided into two (N and N1). III. Each nucleus divides into four (AC and EA). IV. From each quartette a nucleus passes to the centre, and the two fuse to form the endosperm nucleus F, leaving three antipodal cells (AC) at one pole, and at the other the ovum (OV) and two synergid-cells (S). V. The fertilised ovum begins to segment and forms an embryo (EMB) on its stalk (ST); EN, endosperm; A, B, C, the division of the nucleus of the pollen grain to form a generative nucleus (GN) and a tube-nucleus (TN). The generative nucleus again divides.

"The results", Sachs says, "of the investigations published in the *Vergleichende Untersuchungen*, in 1849 and 1851, were magnificent beyond all that has been achieved before or since in the domain of descriptive botany. . . . Alternation of generations, lately shown to exist, though in quite different forms, in the Animal Kingdom, was proved to be the highest law of development, and to reign according to a simple scheme throughout a long series of different

plants." Pre-Darwinian as it was, Hofmeister's picture of genetic affinity between Cryptogams and Phanerogams was a brilliant suggestion of Evolutionism.

Much has been discovered since Hofmeister's day, but the general result has been confirmatory. Among the steps may be noticed the discovery that the sporophyte generation, resulting from a fertilised egg-cell, has the diploid ($2n$) number of chromosomes, while the gametophyte, resulting from an unfertilised spore, has the haploid (n) number. A reduction or meiotic division, halving the number of chromosomes, takes place in the formation of spores (usually four) from a spore-mother-cell.

Very interesting was the discovery, by Ikeno and Hirase, and by Webber, of multiciliate sperm-cells which swim out from the pollen-tube of Cycas and the Maidenhair Tree (Gingko) and link these seed-plants back to ferns.

Improvements in methods have made it possible to detect macro- and mega-sporangia and dimorphic spores in many extinct types; and while a unified genealogical tree of plants is still a dream-picture, various distinct lines of evolution are becoming clearer and more continuous.

Of importance also has been the disclosure of such short-circuiting as apospory and apogamy, and of strange phenomena like xenia—where the pollen nucleus that unites with the endosperm nucleus affects the character of the seed-tissue, just as its fellow, which unites with the egg-cell, affects the embryo.

THEORY.—The question rises as to the meaning of this wide-spread phenomenon of metagenesis or alternation of generations, and the problem must be considered: (1) in relation to other ways in which life-histories are complicated by emphasising or subordinating, elongating or reducing, arcs in the ordinary curve of life; (2) in relation to the fact that the sporophyte is diploid and the gametophyte haploid; and (3) in relation to the advantages that may be discovered in the alternation of sporophyte and gametophyte. The difficulty of the problem is increased by the fact that while the conspicuous chapter in the life-history of. say, a fern is the sporophyte, the conspicuous chapter in the life-history of a moss is the gametophyte. Furthermore, in *some* Algæ and Fungi, where the two phases live in similar conditions, there may be no contrast between sporophyte and gametophyte except as regards the number of chromosomes and the reproductive organs. How great the difference between this and the extreme dimorphism in higher forms, whether Ferns or Flowers!

It is possible that the primitive sequence was Sporophyte-Spore-Sporophyte, and that the interpolation of a Gametophyte was justified because it secured sexual reproduction and in particular

amphimixis. So that the sequence became: Sporophyte-Spore-Gametophyte-Fertilised Ovum-Sporophyte. The sporophyte, with its more vegetative body and its double supply of chromatin, represents the relatively more anabolic preponderance, and its spore-formation had the advantage of securing dispersal. The gametophyte, given over to reproduction to a proportionately greater degree, with a weak vegetative grip in most cases, sometimes unable to survive without a symbiotic fungus (!), and with half the supply of chromatin per cell, represents a relatively more katabolic predominance. Yet in the amphimixis there are the advantages which have been referred to in the section on Reproduction: Thus the pooling of two inheritances, often from separate gametophytes, may promote variability at one time and average off undesirable idiosyncrasies at another.

In comparing alternation of generations in plants with what occurs in many animals, it should be noticed that in the latter the contrast is often between asexual and sexual phases, or between parthenogenetic and spermic development; that there are no spores in multicellular animals except in a few cases like Trematodes; and that the reduction division occurs in the maturation of the egg-cells and sperm-cells.

In a well worked-out theory, Prof. F. O. Bower has associated the later differentiation of plant metagenesis with the colonisation of the dry land. It must be thought of as beginning in water, for it is shown by many Algæ, and the character of the sperm-cell in Cryptogams implies free-swimming. But the increasing divergence of sporophyte and gametophyte may be associated with the establishment of the terrestrial habit. Thus one important feature involved in this change would be the retention of the fertilised egg-cell within the parent-plant—in the archegonium in fact. Since the gametophyte was never at home, so to speak, on dry land, unless in such cases as the moisture-loving liverworts and mosses, there was a tendency to lay more and more emphasis on the more vegetative sporophyte, which gradually became the ascendant terrestrial phase. Finally, yet gradually, what corresponds to the prothallus was retained within the shelter of the sporophyte, as in all seed-plants. The general idea is attractive that the ascendancy of the sporophyte and the dwindling of the gametophyte to a vestige was historically associated with the establishment and advance of a land-flora.

THE FLOWER IN HISTORICAL RETROSPECT.—It is one of the strangest paradoxes of the history of science that neither Linnæus as the father of modern botany, nor even Robert Brown and De Candolle, though establishing the natural system, had ever imagined the real nature of the flower, any more than has the simple field

naturalist, gardener or even florist to this day: and since for adequate understanding of this matter a laboratory course is necessary, no popularisation of this subject is adequately possible, and we can here only give the barest outline of the main result. Linnæus, in establishing for the flowering plants the name of Phanerogamia (evident sexes), expressed this everyday view; yet his reflective intuition as to the apparently flowerless plants—ferns, mosses, equisetums, lycopods, with algæ, fungi, etc.—is manifest in his general name for them as Cryptogamia, which expressed his anticipation that sex was here but hidden, as was in time confirmed. But it was not until the middle of the last century that Hofmeister revolutionised the whole subject, by producing convincing evidence that the so-called Cryptogams plainly and unmistakably exhibited the sexual process of reproduction, and this usually in "alternate generations" with the asexual, as so well demonstrated in the fern. For that familiar type, with its spore-bearing leaves, is but the asexual generation. The sexual generation is the tiny prothallus, at first naturally mistaken for a different kind of plant altogether—a mere liverwort. It is this which arises from the spore. Its small ova are each contained in a flask-like "archegonium", while the male elements are set free from equally distinctive "antheridia". It is the fertilised ovum which develops into the fern anew. The reciprocal case occurs in mosses; for the spore-bearing generation is here reduced to the moss-capsule and its stalk, while the leafy-looking moss body is the sex-bearing generation, in this case the actively vegetative one. This, however, is exceptional, as from the ordinary contrast of vegetative growth and reproductive cost we might expect. Hofmeister's study of the Lycopods was also very helpful: since in these the spores are of two kinds, large and small, megaspores and microspores, the former producing the larger prothalli of the more growing female sex, with their characteristic archegonia, and the smaller spore the small male prothallus, producing fertilising elements.

Passing to the flowering plant, Hofmeister's keen re-examination of the embryo-sac (which after fertilisation produces the plant embryo, long before vaguely known within the ovule), revealed this as a macrospore corresponding to that of the Lycopod. And within this he identified not only the ovum, but the minute homologue of the prothallus; which develops at last into what earlier botanists had called the albumen, and later ones the endosperm. But this attractive identification seemed at first but dubious, for where was the archegonium so characteristic of the higher cryptogams? Here the difficulty was substantially overcome through the examination of the ovules of conifers, which revealed the embryo-sac as megaspore, with ample prothallus, and unmistakable archegonia, though reduced. So next returning to the embryo-sac of the flowering plant, the last vestiges of the archegonium were then reasonably identified.

So in the male sex, the stamen was interpreted as also a spore-bearing leaf, more developed than that which is reduced to a carpel. Its pollen grains were identified, not as themselves the simple and ultimate fertilising elements of previous and still popular belief, but as microspores developing their greatly reduced prothallus as the familiar pollen-tube of the fertilisation process. In this "germination of the pollen grain", its nucleus divides: one of the resultants remaining vegetative, but the other descending to the pollen-tube tip, and thence making its way to unite with that of the ovum. Here, then, is the fullest conceivable reduction of the male generation: yet that this is a true homology has been confirmed by the more recent discovery of active and motile antherozoids produced at the tip of the pollen tube (male prothallus) in Cycads, gymnosperms more primitive than the conifers. So, in brief retrospect, we see how the alternation of generations is continued morphologically and physiologically in "flowering plants"; so that these are now understood as true Sporophytes, substantially corresponding to the ferns and Lycopods we know, though greatly reducing and incorporating their sexual generation into the most profound concealment of all the motherings of nature, so that what was thought the simplest and most obvious of sex-processes, and conspicuously phanerogamic, turns out to be the most disguised and ultra cryptogamic reduction. The evolutionary bearing of all this is not a little impressive, for the apparently utter separateness of so-called flowering and flowerless plants is thus satisfactorily bridged over and rendered intelligible. And this not only morphologically, but also in physiological terms, as an evolutionary reduction of the sexual generation for both its sexes, though the female especially. Yet this sex influence profoundly penetrates back (perhaps with hormones we may some day distinguish?) into the respectively female and male spore-bearing leaves, the carpels and stamens which we call the essential organs of the flower. It even influences the floral envelopes into beauty, most markedly the petals; not infrequently also the sepals, and even in some cases the mothering leaf of the flower—the bract—as well.

This body of discovery as to the real nature of the flower—obviously so evolutionary in its interpretation—is the greatest of compensations for the comparative poverty of the palæontological record, which has as yet yielded so much less of clear and continuous evolutionary series than we now possess for various animal types and races; and indeed, from its perishable nature, it can hardly be expected to do so to any such convincing extent. Yet vegetable palæontology, too, goes on yielding more and more illustrations of various beginnings of flowers and even seeds, and often in plants which long seemed but on the level of ferns or their allies: so taking all evidence from living forms and past forms together, the botanist

feels practically as convinced of the evolutionary origin of plants as does the zoologist for animals.

> The life of plants, rising thro' dim sweet states,
> Cloisters the great love-secret more and more;
> Gathers it jealously within the gates
> Of the hushed heart; yet mightier than before
> The mystery prevails and overpowers
> Stem, leaf and petal. So the passion lies
> In this tranced flowery being which is ours,
> Like to a hidden wound, yet softly dyes
> With dolorous beauty all the stuff of life,
> Each dream and vision and desire subduing
> With muted splendour, the great counter-strife
> Of life with its own rhythmic pangs imbuing—
> Deny it and disdain it—lo there beat
> Red stigmata in heart and hands and feet.
>
> R. A. TAYLOR (*Hours of Fiametta*)

THE MEANING OF LARVÆ

No one who looks round in spring, when so many life cycles are beginning, can fail to be impressed by the frequent occurrence of

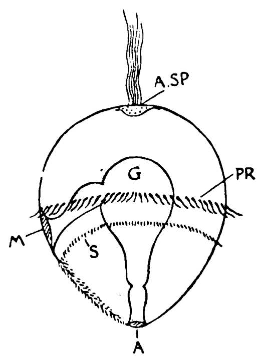


FIG. 133.

Diagram of Free-Swimming Trochosphere Larva of a Sea-Worm. A.SP, apical spot with a few nerve-cells and projecting cilia; PR, pre-oral band of cilia; M, the mouth; G, the food-canal bending round to the anus (A); S, post-oral band of cilia.

larvæ, such as tadpoles and caterpillars. But what are larvæ, and what is their significance when they occur in a life-history?

From the sheep comes a lamb, which no one would dream of calling a larva. Out of the hen's egg there struggles a chick, which no one would dream of calling anything but a young bird. Out of a crocodile's egg, buried deep in the warm sand, there wriggles the very miniature of its parent; and here, again, there can be no talk

of a larva. It is plain, therefore, that the occurrence of larvæ is no necessity, though undoubtedly very common. We see larvæ in the life-history of frogs, many fishes, lampreys, most sea-squirts, many molluscs, all the higher insects, most crustaceans, not to speak of worms, starfishes, and other animals of relatively low degree.

As long as development is proceeding within an egg-shell or egg-envelope, we speak of an embryo. It is in no way able to fend for itself. But when this embryo is hatched out by the breaking of the egg-shell or the egg-envelope we call it a young creature if it is

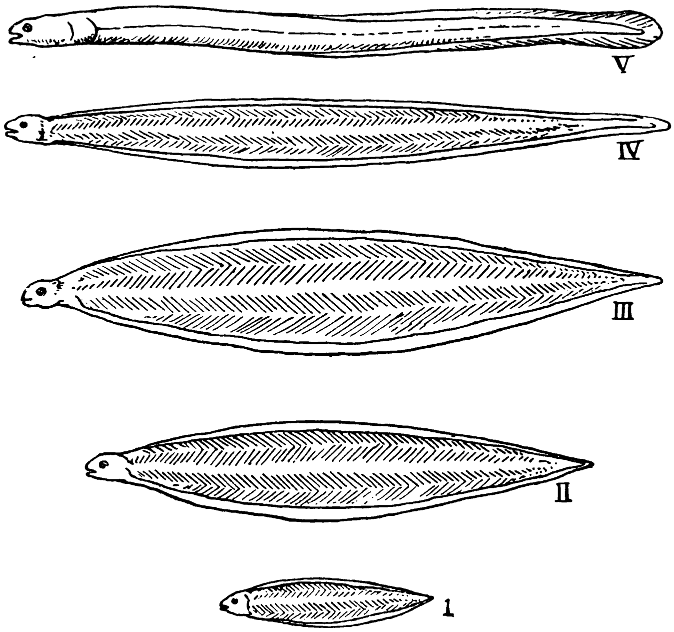


FIG. 134.

Part of the Life-History of the Common Eel (*Anguilla vulgaris*). After Schmidt. I, a very young larva; II–III, stages of Leptocephalus or Glass-Eel growth; IV, the beginning of the change into the cylindrical elver form; V, an elver, ready to ascend the river, about three years old.

in a general way a miniature of its parent; but we call it a larva if it shows a more or less different plan and aspect. Thus no one could say that a caterpillar is at all like a moth or a butterfly, and it takes a strong imagination to see the frog in the tadpole.

The larval eel in the open sea is so unlike an eel that it was called by a different name—Leptocephalus—for many years before it was known to be what it is. Similarly the fresh-water young stages of the big marine lamprey were for many a year called Ammocœtes (or "niners") before their parentage was proved. A hatched-out independent young creature is called a larva when it has a distinctive organisation of its own, different from that of the adult animal.

To put it in another way, the larva has to undergo some sort

of metamorphosis before it becomes an adult. The caterpillar is beginning its metamorphosis before it enters the chrysalis or pupa stage, in which it transforms fully to butterfly or moth. The tadpole is metamorphosed—and also during a period of fasting—into the likeness of a frog or a toad. The free-swimming larvæ of starfishes and sea-urchins have to undergo metamorphosis before they show any likeness to their parents.

The antithesis to the occurrence of larvæ in a life-history is direct development, such as is familiar in ordinary reptiles, birds, and mammals, or in earthworms, leeches, land-snails, and cuttlefishes. We say "ordinary" so as to leave it an open question whether a new-born marsupial, for instance, does not almost deserve the

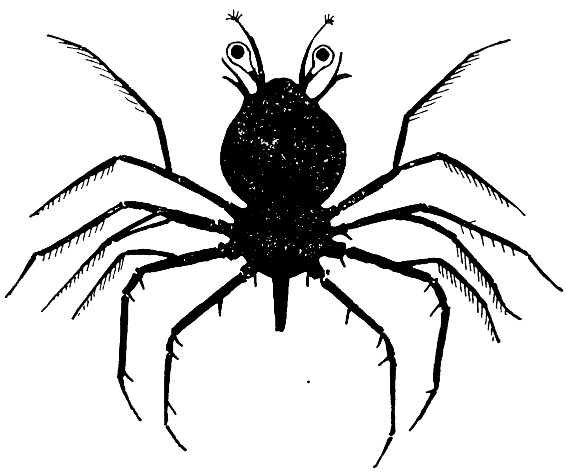


FIG. 135.

Pelagic Phyllosome or Glass-Crab Larva of the Rock-Lobster, Palinurus. After Roule.

designation larva. It used to be a favourite idea that direct development represented a secondary simplification of a long-drawn-out life-history with larval stages. Thus the life-history of a cockroach, where a miniature adult breaks out of the egg-shell, was regarded as less primitive than the typical life-history of all the higher insects, where a larva emerges from the egg, and in the course of a quiescent pupal phase is changed into the winged imago, structurally very different. There are probably some cases where this reduction of larval stages has secondarily occurred, so that a telescoped life-history has resulted; but on the whole the direct type of development is primary, and the interpolation of larval stages is secondary.

The commonly held view nowadays is that larvæ represent secondarily specialised growth-developments arising at some punctuated phase in a direct life-history. The caterpillar is not an

original phase in the primitive insect development; it is of secondary origin, yet with new emphasis. It thus expresses an interpolation, a new chapter, adaptive to certain circumstances, and serving certain purposes.

Two ideas help us to clearness. The first is that any chapter of a life-history, any arc on life's trajectory, may be in the course of generations lengthened out or shortened down, and a larva represents a lengthening out of a youthful phase. The second idea is that the larva is not the interjection or interpolation of a quite novel form, for that would be magical. The larva is a punctuating off of a stretch in the life-history, with an expression and activation of certain features that would in direct development remain in the background, without being called into active exercise. Furthermore, these larval characters are often adaptive to particular exigencies or difficulties of the creature's life.

Out of the egg-case (the "mermaid's purse") of a skate, there emerges, after a long, slow development, a fully formed miniature skate, able to fend for itself. There is no larval phase. Out of the floating eggs of the fishing-frog or angler-fish there emerges a quaint long-tasselled larva, suited for life in the open waters, which it leaves for the floor of the sea as it gradually changes into the adult form. The newly-hatched young (Zoæa) of a shore-crab is superficially very unlike its parent; it is so delicate that it could not survive for a day in the rough-and-tumble life of the upper littoral zone; it is suited for the safer open-sea conditions. It feeds, grows and moults, and becomes a "Metazoæa". As this second larva assumes by metamorphosis the familiar adult characters, it sinks, as a Megalopa, to the sea-floor, when not much bigger than a split-pea; thence it gradually creeps up the slope into shallower water, becoming a miniature shore-crab.

Since every highly-evolved animal does in some measure recapitulate, in its individual development, the history of its race—ontogeny repeating phylogeny—zoologists used often to regard larvæ as rehabilitations of long-lost ancestral types; and this sometimes rightly. In many cases, however, this interpretation is not tenable save in a very general way. It is highly improbable that the caterpillar is at all like any ancestral form of insect; for it is not proved that its attractive resemblance to Peripatus, an annectent type between ringed worms and insects, is much more than of superficial convergence. No one could suppose for a moment that the flattened, transparent "glass-crab", the Phyllosome larva of the rock-lobster (*Palinurus*), is at all suggestive of the ancestry of this magnificent crustacean. Yet we must not swing to the opposite extreme; the surface larvæ of the floor-frequenting flat fishes are nearer the ordinary and ancestral fish-type; and larval ascidians certainly give us more than a hint of the vertebrate pedigree of these strange

degenerate types. Thus we see that the larva cannot be an entirely novel interpolation; it must show some of the hereditary racial characters, however little marked; and it is sometimes plainly recapitulative of an ancestral stage. On the other hand, the details of a larva are peculiarly adaptive to environmental conditions, exigencies, and opportunities.

The question now rises: What are the advantages of larval stages—advantages which have secured the survival of those types that varied in the direction of this staccato phase of life-history? A first advantage may be diffusion or scattering, for mobile larvæ often spread in all directions. This abates overcrowding in the vicinity of the birthplace; and is of particular advantage when the

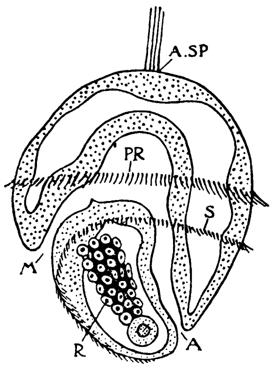


FIG. 136.

Diagram of the Trochosphere Larva of a Sea-Worm, adapted for pelagic life. A.SP, apical spot, with some nerve cells and projecting cilia; PR, pre-oral ring of locomotor cilia; S, a similar post-oral ring; M, mouth; A, anus; the food-canal, lined with endoderm, twists through the body-cavity; R, the beginning of reproductive cells. After Hatschek.

parents are fixed animals, such as crinoids and brachiopods. This spreading may also lead to the discovery of more suitable haunts, to cross-fertilisation when maturity is reached, and to a lessening of the risks of being devoured *en masse*.

Another advantage is that the larva is often in a better position than would be a fully formed miniature to secure a foothold, to accumulate capital in the form of tissues and reserves, and to grow in relative safety. This is well illustrated by caterpillars; they make butterflies possible. Sometimes, moreover, the insinuation of a prolonged larval stage may circumvent the dangers of a difficult season, such as winter. And, again, when the race has made a big and difficult change in habitat, such as leaving water for dry land, a larval period in the old haunt, as in the case of frogs and land-crabs, may save the situation during tender youth. These are some of the reasons why there are so many larvæ in spring.

THE DURATION OF ANTE-NATAL LIFE

One of the trends of organic evolution is towards viviparous birth. That is to say, it has often been found advantageous that the offspring should develop *within the mother*, so that what is born is already well advanced. One obvious advantage of this viviparity, as against the egg-laying or oviparity that obtains in the vast majority, is that the early development goes on in conditions of relative safety, within the body of the mother. Laid or liberated eggs are apt to be discovered by hungry eyes and eaten; and among land-animals they are often in danger of being dried-up.

A correlated advantage of *prolonged* viviparity is that the young creature is very well equipped when it is launched on the voyage of life. In such a familiar case as sheep, the newly born lamb can stagger after the ewe in a surprisingly short time, and everyone has seen that the same is true of the foal which stumbles so quickly after its mother. This is plainly of "survival value" in those gregarious mammals that are often on the move. A third advantage of viviparity is seen in those types in which the unborn offspring is a physiological partner with its mother, living for a prolonged period in nutritive connection with her. This is pre-eminently true of the Placental Mammals, in which there is a very intimate and intricate union, by means of the placenta, between the mother and the unborn young. Though no solids can pass through the placental sponge from the one to the other, there is a diffusion of fluids and gases between the two. The mother contributes to the blood of the offspring (*a*) dissolved food-materials, (*b*) oxygen, and (*c*) some hormones or chemical messengers. The offspring returns to the mother (A) nitrogenous waste-products, (B) carbon dioxide, and, as some say, (C) hormones which enable the mother to make the best of her food. As (A) and (B) are poisonous, the advantage is very obviously on the side of the offspring; yet possibly (C) the offspring helps the mother with a contribution of hormones. The intimate interchange goes on during the whole period of gestation, and the association well deserves to be called a symbiosis or vital partnership. This is a truer view, we think, than is suggested by the old description of the unborn mammalian offspring as a "fœtal parasite".

VIVIPARITY.—Granting viviparity these advantages, we find significance in the fact that it has been attained independently at several different levels in the ascent of life, and has always been rewarded with success for a time at least. One of the most archaic of terrestrial animals, in some ways intermediate between Ringed Worms (Annelids) and the insect-centipede stock (Tracheata-

Antennata), is a widespread type called Peripatus, which, with other nearly related genera, is included in the class Onychophora or Claw-bearers. This relic of an ancient fauna holds its own partly because of its shy elusive habits, hiding under bark, in rotting wood, and among moss; and partly because of its unique way of feeding, for it squirts jets of gluey slime on small insects that pass by; but also *because it is viviparous.* The young one is nurtured for a long time within the mother—for thirteen months in the Cape species—and it is born fully formed, a miniature of its parents, more or less able to fend for itself. This is the reward of viviparity.

Unfortunately for Farming and Gardening, great success, as regards material well-being and increase in numbers, has attended the pests known as Aphids, Greenflies, or Plant-lice; and it is not a coincidence that throughout the summer months these theoretically fascinating, but practically detestable, insects are *viviparous.* In the summer months there are no males, and the parthenogenetic females produce their offspring viviparously. What leaves the virgin mother is an almost perfect greenfly, able at once to suck the sugary juices of plants; and in the course of a week or so this viviparously-produced daughter-Aphis is able to continue the prolific succession. Agriculturally speaking, we wish this viviparity did not exist, but there it is!

We must not linger in this side-alley of our main theme, but the point is that over and over again in the course of organic evolution a trend towards viviparity has found expression. It must suffice to notice that the outcome of this recurrent trend is illustrated in various orders of insects; in a few fishes, amphibians, and reptiles; and that it becomes the rule in Mammals.

More Than Viviparity.—In two of the viviparous sharks and in several viviparous lizards there are interesting anticipations of the *placenta,* which is so distinctly characteristic of ordinary Mammals. That is to say, at the low level of these two fishes, as Aristotle pointed out more than two thousand years ago, a nutritive connection has been established between the unborn offspring and the wall of the mother's oviduct. It is also of interest to remember that the seeds of Flowering Plants, as distinguished from the spores of Flowerless Plants, are well-equipped offspring which have developed for a considerable time in nutritive dependence on the parent plant, within which they are hidden away. The comparison must not be pressed, yet it is more than a coincidence that botanists should speak of the *placentation* of the ovules within the ovary.

Oviparous and Marsupial Mammals.—When some wide-awake natives of Australia first told the exploring zoologists that the Duckmole laid eggs, the report was received with natural incredulity. A mammal could not possibly lay eggs. But the natives were right and the textbooks were wrong: there are two types of

oviparous mammals—the duckmole (Ornithorhynchus) and the Spiny Anteater (Echidna). The duckmole lays two eggs in a nest in a burrow; the Spiny Anteater, after liberating its single egg, takes it in its mouth and places it in a temporarily developed skin pouch. The eggs of these "Monotremes", as the oviparous mammals are called, contain a considerable quantity of yolk, which is practically absent from the much smaller ova of other mammals. The ova of ordinary mammals are usually about the size of small pinheads, but those of the oviparous types of Monotremes, to which we have referred, are $\frac{1}{8}$–$\frac{1}{6}$ inch when they pass from the ovary into the oviduct, and $\frac{3}{5}$ by $\frac{1}{2}$ inch when they are extruded. This relatively large size, which means that there is a considerable quantity of yolk, is obviously correlated with the fact that the development of those Monotreme eggs takes place for the most part *outside* of the mother. When the young one is hatched, whether in the nest (Duckmole), or in the pouch (Echidna), it begins to lick the mother's skin on the area (on the under surface or in the pouch) bearing the numerous apertures of the milk glands, which are devoid of teats or mammæ. In these and in many other ways the Monotremes are obviously very old-fashioned. Perhaps we should notice that most authorities distinguish a third genus, Proechidna, also oviparous, and nearly allied to Echidna. This detail does not affect our argument.

Among Marsupials there seems to be only one type, the tree bandicoot or Perameles, which has the true (allantoic) placenta that is found in all ordinary mammals. The other marsupials do not get beyond a makeshift (yolk-sac) placenta, which also occurs as a transitory stage in the gestation of Rodents, Insectivores, and Bats. Thus the ante-natal partnership between the Marsupial mother and her offspring is not so intimate as that obtaining in ordinary mammals. Not only so, the gestation is very short—in some cases only a fortnight. In the large species of Kangaroo (*Macropus giganteus*), which may stand as high as a man, the period of gestation is only thirty-nine days; and then the young one is born, blind and naked, very imperfectly finished, and not much more than an inch in length! The prematurely born young marsupials are peculiarly helpless, but they have the instinct to climb about on the under side of the mother and to enter the skin-pocket or marsupium if they succeed in reaching it. Indeed, they are so helpless that they cannot even suck the mammæ to which they become attached inside the pouch, which is developed in most, though not all, of the female Marsupials. The milk has to be forced down their gullet by the contraction of a special (cremaster) muscle around the mammary glands; and there is an interesting adaptation—the shunting forward of the top of the windpipe into the posterior nares—which enables the young one in the pouch to continue

breathing while the milk is being forced down its throat. The temporarily continuous passage from the nostrils onwards allows the air to pass down the windpipe to the lungs, but prevents the milk going down the wrong way.

Another very interesting adaptation is that the teat or mamma swells inside the young marsupial's mouth, so that the very helpless creature is not likely to lose its hold. But the most important point is the general one, that the short gestation is correlated with a very half-finished state at the time of birth, a drawback which is met by the development of the marsupium or pouch. Thus the hint that we get from the remarkable state of affairs in marsupials is that a prolongation of the period of gestation is likely to be associated with the better equipment of the newly born young one. It would be easy to find a female Kangaroo about the same size as a Shetland pony mare; but the former carries its young for 39 days before birth, and the latter for eleven months. Our proposition is that the extension of the duration of ante-natal life has been one of the conditions of the precocity of the newly born foal—an idea that was first promulgated by Robert Chambers, the pre-Darwinian evolutionist, who wrote *The Vestiges of Creation* (1844).

LENGTH OF GESTATION.—There is evidently some puzzle in the great variety in the length of the ante-natal period in different mammalian types. "Why does the seal take eleven or twelve months for gestation when a large dog requires only nine weeks?" (F. H. A. Marshall, *Physiology of Reproduction* (1910).) Why does such a highly specialised mammal as a bat have a short gestation—in some species seven weeks—while in another climax of specialisation, the elephant, it is twenty months, or even over two years? Why should a tigress carry her unborn young for twenty-two weeks, while the period for the nearly related lioness is sixteen?

PECULIAR CASES.—In some mammals there are altogether peculiar features which must be kept by themselves, and not allowed to complicate the general problem. Thus in some of the European bats the pairing and insemination normally occur in autumn, whereas the ovulation and fertilisation are delayed till the following spring. It seems that the spermatozoa remain stored in the genital duct of the female throughout the whole period of hibernation. In some other mammals, where the fertilisation immediately follows the insemination and the development begins at once, just as is usual, there is a strange arrest of development for a prolonged period. Thus Marshall notes that while roedeer in Germany pair in autumn, the embryo does not develop beyond the segmentation stage till the following spring. There is often a long arrest in the development of the badger.

THE GENERAL THEORY.—Many variations in the length of the ante-natal period in mammals have been recorded, especially

towards an *increase* in the time; and thus it is quite legitimate to postulate variability in the length of gestation. This variability might be prompted by variations in the endocrinal or hormone-making system of the offspring, or in its capacity for making most of the food; but it is enough to say that as regards gestation, as elsewhere, variations in the rate or *tempo* of development are common. If these variations are continued in the inheritance from generation to generation, and if they are advantageous, then a change in the length of the ante-natal life might become a new specific character.

Thus the question comes to be whether changes in the length of gestation may be of survival value. Are they so advantageous or disadvantageous that they might come to be sifted in the course of Natural Selection?

On the whole there is an advantage in economised reproductivity, since it lessens the strain on the mother. But a gradual reduction in the size of the family is hazardous unless there is some associated variation which increases the chances of the offspring's survival. This may be effected by an increased parental care, especially on the mother's side, as may be illustrated by bats, which carry their young one through the air. The very helpless offspring of monkeys and apes is often carried about, and the mortality seems to be low. Or the offspring may be hidden away, as wild cattle hide their calf in the thicket, and wild deer their fawn. Or it may be through a den that the safety of the family is secured, as in many Carnivores. But it is plain that another way in which the safety and success of the young offspring may be secured is by delaying its birth until it is more or less able to fend for itself. A lengthening out of the gestation allows the young creature to attain to a relatively advanced state before it is born; and Robert Chambers had the shrewd idea that a prolonged period of quiet development would favour the evolution of the brain. Thus there might result an improvement of intelligence and a reduction in the scope of instinct. The prolonged gestation of elephants (20 months), camels (13 months), horses (11 months), cattle (9 months), may be referred to in illustration. A prolonged quiet development of the brain, with abundant nutrition but without much excitement or activity, would favour cerebral advance.

While there are many cases where prolonged gestation is associated with an advanced development of the brain at birth, thus giving the young creature a good send-off, as far as wits are concerned, there is no doubt that the same result might be reached by having the litter in some safe retreat, as in many carnivores. In such types the gestation may be relatively short, e.g. four or five months in the badger, which may be deceptively lengthened out in individual cases by the interpolation of a period of arrest. The gestation of the

puma is said to be only fifteen weeks. It should also be borne in mind that while there is an obvious advantage in being born well-equipped in body and mind, as in the foal, a similar success may reward an animal born at a much less advanced stage, provided that it be safely hidden away and carefully educated by its parent or parents. The detailed education which the mother otter gives her cubs is well known, and there are many other instances.

Apart from the reward that comes to precocious intellectual development, another advantage of prolonged gestation and advanced equipment at birth may be recognised in cases where the habitat is very peculiar, with unique difficulties. Thus a young Cetacean must be able to swim and dive at birth, and it must also be able to suckle in the water. It is not surprising then to find that the gestation of porpoises and dolphins lasts for about ten months. Similarly, not much is known of the intellectual gifts of the walrus, but there is no doubt as to the difficulties of its boreal haunts, and it is not surprising to find that its gestation lasts about a year, and the lactation or nursing period for about two years. This is an exceptional case that tests the rule or thesis, that prolonged gestation gives the young creature a good start.

There are, no doubt, other factors to be considered in interpreting the length of ante-natal life as adaptively adjusted in the course of Natural Selection. (*a*) Thus when there is a regularly recurrent pairing time, there may have been a lengthening out, or perhaps a shortening down, of the gestation so as to ensure that the young ones are born at a suitable time of year. This seems to be brought about in certain cases, such as the badger, by a *modificational adjustment,* meaning by this phrase that changes in the rate of development are directly impressed on individuals by environmental, nutritive, and functional peculiarities. For instance, while conception may occur, they say, in the badger at any time of year, "the young are invariably born within a period limited to six weeks". This fact, cited from Marshall's admirable *Physiology of Reproduction,* to which we are as gratefully as obviously indebted, can only be explained, so far as we see, on the theory that unpropitious environmental conditions bring about an arrest of development, and this standstill has been actually demonstrated in the somewhat extraordinary case of the badger. But apart from such difficult cases, it seems reasonable to suppose that an adaptation of length of gestation to birth at appropriate seasons might be readily effected, if the length of gestation is a variable specific character, and if being born at an inappropriate time is rapidly fatal. If man can by reasonable interference secure that lambs and calves and foals are not born at very unfriendly times of year, there is no improbability in the theory that this sort of adjustment of time of birth and length of gestation to seasonal conditions may have

been wrought out in the course of time by Nature's automatic sifting.

(*b*) Something must also be allowed for size. Thus Prof. Sedgwick, a very shrewd zoologist, pointed out that "the duration of gestation depends on the size of the body and on the stage of development at which the young are born". This statement is perhaps a little tautologous in its second statement, since it is, in many cases, the length of gestation that seems to make the difference between being born rather helpless and being born with precocious powers. But as to the first statement, there is no doubt that a large animal, such as an elephant or a whale, demands a long gestation. But even this conclusion must not be pushed too far, for wild swine have a gestation of about four months, about the same as in the much larger lion.

Thus we wish to rehabilitate the suggestion of Robert Chambers, that the lengthening out of the period of gestation is an adaptive change which has had as its survival value the advantage that the offspring are born with better brains and otherwise more fully equipped for the struggle for existence.

DURATION OF LIFE

Most animals, clearly, have a normal specific size, to which the great majority of the adult members of the species closely approximate. In a large collection representing a species there may be a few giants and a few dwarfs; but most of the members show a close approximation to the same limit of growth: and there are good reasons for believing that this normal specific size is *adaptive*; i.e. that it has been slowly established in the course of selection as the fittest size for the given organisation and the given conditions of life. In some cases, e.g. many fishes, there is no such definite limit of growth; thus haddocks may be found as large as average cods, e.g. over two feet long.

Similarly in many animals that have been carefully studied we find that there is a normal potential duration of life,—an age which is rarely exceeded, though it may be seldom attained. This normal "lease of life" is in most cases known only in a general way; but in many cases we are able to say that the living creature in question never lives longer than a few months, or a year, or a few years. Statistics from forms kept in captivity are obviously vitiated by the artificial conditions, and the life of animals in their natural conditions is so often ended by "a violent death"—coming sooner or later according to the varying intensity of the struggle for existence—that it is difficult to say what the normal potential duration of life really is. But a critical survey of a large body of facts led Weismann,

in his essay *On the Duration of Life* (1881), to the conclusion that this, like size, is an *adaptive character*, gradually defined by selection in relation to the external conditions of life and the needs of the species. Given a certain rate of reproduction and a certain average mortality, the duration of life that becomes established will be that which is fittest to secure the survival of the species in the existing conditions. In other words, those species or varieties survive which have attained to a viable correlation between the length of their effective reproductive life and the average mortality. It would handicap a species or variety if its members produced numerous offspring after they had ceased to be effective parents, and if the number of these weaklings and defectives went far in excess of the chances of death.

There are three considerations that seem to us to show that Weismann's theory requires to be supplemented. The first is that he does not allow enough for the constitution of the organism. It is not every kind of organism that could lengthen out its life-tether to meet the demand for a sufficient number of offspring to balance the chances of death. Secondly, the situation might be saved if the organism increased its fertility without lengthening its life. Thirdly, the process of selection, which Weismann postulated, for the adjustment of the length of life to the needs of the species, would operate through the elimination of variants which continued their reproductive period beyond the time of effective parentage, or else would shorten their reproductive period so much that the birth-rate would cease to balance the death-rate: so in either case there would tend to be automatic elimination. But in many organisms the total duration of life is long because of the extension of pre-reproductive periods—an extension which would not be affected by the selection process on which Weismann relied.

Again, an animal after the reproductive age of vigour may continue its life by a change of habits, as of feeding, etc. This may be the case with "man-eaters" in India, which are known to be often old and mangy.

Diversity of Age among Animals.—Let us consider, then, whether any constitutional reasons can be found for the great diversity in the ages that different kinds of animals may attain. The difficulty in finding an answer is largely due to the paucity of secure data. From records of captive animals we know that an elephant may live two hundred years, a parrot eighty, a sea-anemone sixty-six, a golden eagle fifty, a toad forty, a crayfish twenty, a blackbird eighteen; but we cannot assume that these figures hold for the same animals living in natural conditions. In some cases the captive animals may live longer, in other cases shorter, than their relatives in freedom. The data are very uncertain.

Yet in spite of this, attempts at generalisation have been made along various lines.

(1) There is a widely accepted view that large animals, like elephants, have long lives; while small animals, like shrews, have short ones. There is probably a grain of truth in this, for large size usually means considerable capitalisation of energy; so a wealth of reserves should tend, other things equal, towards the prolongation of life. But the generalisation will not work. A cat or a toad may live as long as a horse, say forty years; and a crayfish as long as a pig, say twenty years.

(2) Another generalisation, suggested by Flourens, is that the length of life is normally about five times the period of growth. Here, again, there is a grain of truth; for a long-drawn-out growing period implies laying very secure foundations on which a stable adult life may be based. But this theory will not fully work either. The common eel grows for five to eight years; but it seems to die abruptly after its first and last spawning. A horse is mature in about four years, yet may live to be forty. Some insects go on slowly growing as larvæ for several years (indeed, the larva of the famous American Cicada may live for seventeen years), and yet die in the first year of maturity.

(3) Another of these general ideas, also with some sense in it, is that very active animals wear themselves out quickly, while those that take things easily live long. Worker-bees, victims of an exaggerated instinct for industry, do not usually live for more than six weeks in the summer season—a short life, and not a very merry one. But a sea-anemone, which lives without sound or fury, may last longer than man; olive-trees may survive for very many centuries, and giant Sequoias of Yosemite have been growing quietly for the past three thousand years. The unexcitable carp may live as long as the strenuous elephant; but a sluggish snail does not live so long as the active thrush. The fact is that by choosing suitable types one can argue for or against any of these generalisations.

This has led many back to Weismann's view that the duration of life has been punctuated from without, rather than from within, and has been determined by natural selection. Let us take an illustration.

The Golden Eagle, weighing nine to twelve pounds, is intermediate as regards weight between hare and fox. All three are very strenuous; all three are intricate masterpieces; all three hold their own. But while the hare lives ten years and the fox fourteen, the Golden Eagle attains to sixty! Weismann's interpretation is that the Golden Eagle needs to live so long, if it is to keep its foothold in the struggle for existence. It *must* live for a long time, so to speak, for it takes ten years to mature, and then has only two eggs in the year. The two mammals are much more fertile than the bird;

therefore the fox and the hare do not require to live so long as the eagle.

It is not for the welfare of the species that an animal should continue to multiply when it is past its best—that is the one limit; but it is not for the welfare of the species that the birth-rate should fall below the death-rate when food is abundant and the area not overcrowded—that is the other limit. In reference to these issues the length of life has been regulated by selection.

The illustration just given indicates the shrewdness of Weismann's theory that the duration of life has been determined by Natural Selection; yet we return to our criticisms, (1) that the same result might be reached if the Golden Eagle increased the number of eggs in its clutch, or had two families in the summer—both frequently variable characters among birds; and (2) that the process of selection indicated by Weismann would not operate in regard to the ten years of the Golden Eagle's pre-reproductive life. But our radical objection to the theory as it stands, still is that it takes too little account of the constitution of the organism. It is easy to say that the organism must live longer if it is to meet by its reproductivity the chances of death; but all things are not possible to all sorts of organisms. Thus, without rejecting the view that the duration of life is punctuated by natural selection in relation to the needs of the species, we plead for a recognition of the existence of long-lived and short-lived physiological constitutions. Selection can only operate within limits—limits of constitution, an established metabolic ratio. The long-lived types stave off the ageing or senescence to which all complex animals are liable; but for the short-lived types this is not possible. But how can an organism stave off natural senescence? They may have a highly-efficient regulatory system (hormonic in particular), which harmonises or orchestrates the bodily activities; they may have great capacities for recuperation, by means of long rests, perfect sleep, and frequent changes of food and environment; they may have evolved a power of resistance to frequently recurrent vicissitudes; and they may have a mode of reproduction which is not so physiologically costly as that of lampreys, or butterflies, or Century Plants. These qualities are no doubt themselves the outcome of the selection of variations, but they afford material on which the subtler punctuation of life may operate.

In the case of man we must clearly distinguish between the *average species-longevity*, still only about forty years in Europe generally, but raised to nearly fifty in Britain during the past century or less—but happily raisable substantially further with decreasing infantile mortality, improved sanitation, decreasing warfare, increasing temperance and carefulness,—and the *potential species-longevity*, which for our present race seems normally between seventy and one hundred years. There is no warrant for fixing any

ultimate limit, either for the past or the future. All that we can scientifically say is that there are few well-established instances of a greater human longevity than 104 years. Sir George Cornewall Lewis did good service (1862) in destructively criticising numerous alleged cases of centenarianism, the occurrence of which he at first regarded as quite unproved; but even he finally admitted that men do sometimes reach a hundred years, and that some have reached one hundred and three or four. Thus witness M. Chevreul, a grand old man if ever there was one. The famous cases of Thomas Parr, Henry Jenkins, and the Countess of Desmond, said to be 152, 169 and 140 respectively, were ruled out of court by Mr. Thoms, who edited *Notes and Queries* at the time when Sir G. C. Lewis's wholesome scepticism created much stir. As man is a slowly varying organism, as regards physical characters at least, it is extremely unlikely that his longevity was ever much greater than it is now. Monsters in age and monsters in size are alike incredible.

Metchnikoff was one of the few modern biologists who dealt generously with biblical and other old records of great human longevity. He apparently thought there has been some misunderstanding in regard to Methuselah's 969 years or Noah's 595, but he accepted the great ages of 175, 189, and 147 years ascribed to Abraham, Isaac, and Jacob. But early age-reckonings seem to have been in lunar months; which would bring down Methuselah to seventy-five: and statistics of longevity are by the admiring juniority of their observers and recorders peculiarly liable to exaggeration, as we can see around us to this day. Similarly, he accepted the 185 years with which St. Mungo, of Glasgow, has been credited. And as he was generous in regard to the past, he was hopeful in regard to the future, believing that a more careful and temperate life, as well as an enlightened recognition of the disharmonies of our bodily frame, may bring about a time when man will no longer, as Buffon says, "die of disappointment", but attain everywhere "a hundred years". "Humanity", Metchnikoff said, "would make a great stride towards longevity could it put an end to syphilis, which is the cause of one-fifth of the cases of arterial sclerosis. The suppression of alcoholism, the second factor great in the production of senile degeneration of the arteries, will produce a still more marked extension of the term of life. Scientific study of old age and of the means of modifying its pathological character will make life longer and happier." He also quotes the theoretically simple conclusion of Pflüger's essay on "The art of prolonging human life"—"Avoid the things that are harmful, and be moderate in all things".

A fact of interest is the statistical evidence that such a subtle character as "longevity" (that is to say, a tendency to a certain lease of life, be it long or short) is heritable like other inborn characters; though it rests, of course, to some extent with the individual

or his environment to determine whether the inherited tendency is realised or not. Just as stature is a heritable quality, so is potential longevity; but the degree of expression is in part determined by "nurture" in the widest sense.

We may usefully recognise four categories of phenomena in connection with age. (1) The first is that of the immortal unicellular animals which never grow old, which seem exempt from natural death. (2) The second is that of many wild animals, which reach the length of their life's tether without any hint of ageing, and pass off the scene—or are shoved off—victims of violent death. In many fishes and reptiles, for instance, which are old in years, there is not in their organs or tissues the least hint of age-degeneration. (3) The third is that of the majority of civilised human beings, some domesticated animals, and some wild animals, in which the decline of life is marked by normal *senescence*. (4) The fourth is that of many human beings, not a few domesticated animals, e.g. horse, dog, cat, and some semi-domesticated animals, notably bees, in which the close of life is marked by distinctly pathological *senility*. It seems certain that wild animals rarely exhibit more than a slight senescence, while man often exhibits a bathos of senility. What is the reason of this?

There is, as we have hinted, reason to believe that natural death is not to be simply regarded as an intrinsic necessity—the fate of all life: we can carry the analysis further, and say that it is incident on the complexity of the bodily machinery, which makes complete recuperation wellnigh impossible, and almost forces the organism to accumulate arrears, to go into debt to itself; that it is incident on the limits which are set to the multiplication and renewal of cells within the body: thus the number of brain cells in higher animals cannot be added to after birth; and it is incident on the occurrence of organically expensive modes of reproduction, for reproduction is often the beginning of death. At the same time, it seems difficult to rest satisfied with these and other physiological reasons; and to a considerable extent we have to fall back on the selectionist view that the duration of life has been, in part at least, punctuated from without and in reference to large issues; it has been gradually regulated in adaptation to the welfare of the species.

The majority of wild animals seem to die a violent death before there is time for senescence, much less senility. The character of old age depends upon the nature of the physiological bad debts, some of which are more unnatural than others, much more unnatural in tamed than in wild animals, much more unnatural in man than in animals. Furthermore, civilised man, sheltered from the extreme physical forms of the struggle for existence, can live for a long time with a very defective hereditary constitution, which may end in a period of very undesirable senility. Man is also very deficient in the

resting *instinct*, and seldom takes much thought about resting *habits*. In many cases, too, there has come about in human societies a system of protective agencies which allow the weak to survive through a period of prolonged senility. We cannot, perhaps, do otherwise in regard to those we love; but it is plain that our better ambition would be to heighten the standard of vitality rather than merely to prolong existence, so that if we have an old age it may be without senility. Those whom the gods love die young, aged in years though they may be. But here we leave the problem of longevity to Mr. Bernard Shaw, with hopes of his further and practical continuance of investigation and exposition.

THE BIOLOGY OF DEATH.—Death may be defined biologically as the irrecoverable cessation of bodily life. The use of the word "irrecoverable" is to evade the difficulty raised by states of latent life, where the seed, the germ, the vinegar-eel, the wheel animalcule, the water-flea, and so forth, lie low for months or years without showing any of the customary signs of vitality, and yet do not die. They lie like wound-up watches which have stopped, though they will begin to tick again when they receive some stimulus jar. It is difficult to understand how a living organism can revive after having been brittle for months. Ordinary living matter or protoplasm contains at least 75 per cent. of water.

But, leaving aside the difficulty of animals that lie low, in a state of suspended animation, we may profitably inquire into the different kinds of death that are continually occurring in Wild Nature. In the first place, and easiest to understand, there is violent death, to which the majority of animals succumb. It is due to some violence that shatters or fatally damages an essential part or the whole of the organism. The shot makes holes in the rabbit's circulation or brain; the grouse is crushed in the eagle's talons; the frog is frozen stiff in the drain-pipe near the pond; the trout is swallowed by a pike; the snail is obliterated in the landslide; the starfish is broken under the stone dislodged by the waves.

So it is all over the world—crushing and bruising, freezing and burning, smothering and blowing away; accidents will happen. And being eaten by another animal is so common that it has ceased to be an accident. The conjugation of the verb to eat never stops, and we have to soothe ourselves as best we can with Darwin's words: "When we reflect on this struggle, we may console ourselves with the full belief that the war of Nature is not incessant, that no fear is felt, that death is generally prompt, and that the vigorous, the healthy, and the happy survive and multiply." There is much truth in Goethe's saying that death is Nature's device for securing plenty of life; and we may add that Nature usually sifts towards health and vigour, as with the mutually increasing swiftness

of hare and hound, deer and wolf. Evolution is, on the whole, integrative.

In connection with accidents, we should keep in mind the widespread occurrence of regenerative capacity, whereby the maimed can be mended and the lost part replaced. This wanes in higher animals which have nimble wits to save them, but it is very common among lower forms of life, such as starfishes, worms, and long-legged crustaceans. According to Lessona and Weismann, regeneration tends to occur in those animals and in those parts of animals which in the natural conditions of their life are peculiarly liable to non-fatal injury.

Thus the chamæleon is one of the few lizards that has lost the regenerative capacity and cannot re-grow its tail; and we reasonably correlate this with the fact that the tail is not usually vulnerable, being kept coiled round the branch. In one starfish, at least, the continuance of the race is in part secured by the habit of breaking off an arm which can, if it is lucky, grow into a complete animal. But our point is simply that against the frequency of accidents we must balance the astonishing power of repair which many animals exhibit. Even birds, with legs, wings, or even sternum broken in flight, as by collision with an unnoticed telegraph wire, may marvellously recover, and fly again for years after. Much more important, however, is the resourcefulness and the wealth of adaptations that the chances of violent death have helped to evolve.

The second kind of death might be called intrusive, microbic, or parasitic; and it is the commonest end for man and his domestic animals. We have become so familiar with the frequency of microbic death that we have long fallen into a fatalistic acquiescence, which still retards the advance of preventive medicine. Bacteria are directly responsible for plague, cholera, tuberculosis, diphtheria, typhoid, and so on through the long (but probably shortening) list of microbic diseases.

But apart from the diseases due to bacteria—which seem to be a kingdom by themselves, though the greedy botanist long claimed them—there are others which are due to microscopic animals. Thus there is the Plasmodium which causes malaria when introduced into man's blood by the bite of an infected mosquito, and there is the Trypanosome, which causes sleeping sickness when injected into man by the Tsetse fly. The list of virulent Protozoa continues to grow; and Protozoology is now a specialism by itself, like Bacteriology.

Besides disease-causing Bacteria and Protozoa, there are the filterable viruses, implicated in such diseases as smallpox and hydrophobia, which cannot be referred to any definite group. Of most of them as yet we have only a physiological and an ultramicroscopical knowledge. There is a difference between being

detected by the ultra-microscope and being seen by the microscope which may be understood by pondering over the way a beam of light shows us the usually invisible motes in a shaded room.

How do microbes cause death? This is one of those readily asked questions which require a volume for their answer, but we suppose that an expert in these matters would broadly say that they often make holes in tissues, and that they often poison the body or some part of it with their waste-products. In other words, they act as larger parasites may do, such as some threadworms which not only cause lesions, but exude toxins. Speaking of threadworms reminds us of the remarkable work of Prof. Fibiger, who recently received a Nobel Prize. He showed that the presence and pressure of a threadworm, called Gongylonema, in the rat's stomach induces a form of cancer; and the same sort of consequence occurs, at the lagoon called the Kurisches Haff, in people who eat imperfectly cooked fish containing a certain parasite.

While some parasites pursue their characteristic drifting life of ease, like somewhat passive unpaying boarders, with an impoverishing and an evil influence, there are others which make aggressive attacks on their host, sucking the blood like the hookworm, or actively destroying red blood corpuscles like the malarial organism, or moving about in the body like the larvæ of warble-flies, and so on. There should be some way of verbally distinguishing these aggressive forms from the typical parasites. They are, as a matter of fact, beasts of prey that work from the inside instead of from the outside.

The third kind of death is natural death—the result of the slow mounting up of fatigue-effects, especially in hard-worked organs like liver and kidneys, heart and brain. Natural death is due to the accumulation of the unrecuperated results of wear and tear. Recent investigation, especially that of Prof. Child, seems to show that it is not the living matter that gets tired, but the furniture of the laboratory, so to speak. The less labile framework of the cells, within which the protoplasm works, becomes gradually worn. No doubt there are processes of repair and recuperation—in nutrition, in rest, in sleep, in change, and, in some lower animals, in remarkable processes of tissue-scrapping followed by reconstruction.

But in the long run senescence gets the better of rejuvenescence, and the organism "dies a natural death". In many cases a slight environmental gust, like an unusually cold wind, sweeps the aged player off the stage. But though the punctuating full stop may be inserted violently, the real cause of death is "natural". "And so, from hour to hour, we ripe and ripe; and then, from hour to hour, we rot and rot. And thereby hangs a tale".

The only animals that escape natural death are some of the Protozoa. They are so simple in structure that they seem continually

and perfectly to recuperate their wear and tear. They multiply so inexpensively that there is no Nemesis on their reproduction. As Weismann long ago pointed out, they enjoy a protoplasmic immortality. Natural death was the price paid for having a body.

PLAY IN ANIMALS

Play is illustrated by kittens with their ball, puppies and their sham-hunt, lambs and their races and game of "King o' the castle", monkeys and their "follow my leader". There are often sham-fights among birds which seem to be entirely playful, besides exhibitions of flying powers that have no direct usefulness. For that is one of the criteria of play, that it is not directly useful. Play is not work, though it may be as strenuous and may lead to exhaustion; it is not mere exercise, though, perhaps, it exercises best; it has no deliberate (or, in animals, perceived) end, for the sake of which it is played; and yet it may be almost indispensable if the animal is to attain to the full use of its powers. Play is not necessarily social, for many a kitten plays alone; and it is not necessarily competitive, though rivalry may give it zest. Its keynote is its anticipation of modes of activity which are characteristic of adult life.

Play is well illustrated by many young Carnivores, such as cats, dogs, foxes, otters, and bears; by many young Ungulates, such as lambs, kids, calves, and foals; by most monkeys, and by less familiar cases like young squirrels and water-shrews. Yet it cannot be said to be a general feature in the youthful life of mammals. It is not common among birds; it is only hinted at in reptiles, amphibians, and fishes; and it is at most rare among backboneless animals. This raises the question why a playing period should be interpolated in the life-history of only a small minority. There must be some particular biological advantage in play, yet one which only certain types have been able to secure.

(1) The poet Schiller suggested that animal play is an expression of overflowing energy. It is the byplay of exuberant vigour and animal spirits. But while this theory has its grain of truth, it is far too simple. Thus there are many young animals with abundant vigour that never play; and it is well known that a thoroughly tired animal, such as a dog, may turn in a moment from fatigue to play, as children often do. Moreover, half of the problem is that different types of mammals play in characteristic or specific ways.

(2) Schiller's theory of play was re-expressed by Herbert Spencer, with the important additional suggestion that imitation accounts for the particular form that the playing takes. The physiological condition of play is superfluous energy, but imitation defines the

channel of expression. Young creatures mimic in play what they see their seniors doing in earnest. Here, again, there is some truth, and a corroboration may be found in the imitativeness of certain forms of playing in children. But Spencer's theory will not cover the facts. Thus it has been shown experimentally that an isolated young animal, such as a kitten, will play, and will play true to type, provided that an appropriate liberating stimulus, apart from imitation, is supplied at an appropriate time. But if a kitten reaches a certain age—usually about two or three months—without having had any experience of mice, it will not afterwards show any "mousing instinct", nor any capacity for playing with a mouse.

(3) A third idea has some relevance, namely, the close correlation between pleasant emotions and bodily movements. It is a familiar fact of experience, elaborately studied by the physiologists and psychologists, that pleasant feelings reverberate in various parts of the body, such as the heart, the lungs, the larynx, the food-canal, and the bladder. The correlation of emotional excitement and the activity of the suprarenal bodies is well known. But to the internal movements there may be added movements of the body as a whole, and these will be naturally specific for different types. The child dances with joy; the otter cub gambols exuberantly. This simple movement-play may be a useful safety-valve, but it is also a natural expression of overflowing *joie de vivre.*

(4) To Karl Groos we owe the illuminating suggestion that play is especially important as an irresponsible apprenticeship to the subsequent business of life. It is the young form of work, and this accounts for its specificity. The young Carnivore has its sham hunt, and the young Ungulate its amateurish race, neither involving serious responsibilities. Under the shelter of parental or communal care the playing animal educates powers that are essential in its after-life, and is afforded opportunities without the serious consequences which are involved whenever the struggle for existence sets in keenly. As Groos puts it, animals do not play because they are young, they continue young in order that they may play. No doubt non-playing young animals also educate their capacities, but the point is that the interpolation of the play-period is an additional advantage which some plastic and well-endowed creatures have been able to secure for themselves. It is interesting to notice that most of the mammals that man has succeeded in domesticating are playing mammals.

(5) Another aspect of the play-period is that it affords opportunity for testing new variations before the day-by-day sieve of the struggle for existence becomes too close in the mesh. Play affords elbow-room for new departures; and its value is particularly clear when the adult life is very varied, like an otter's, demanding plasticity and resourcefulness. Here there is a marked contrast

between games, which are restricted to mankind, and *play*, which children share with young animals. For the game has its rules, and demands self-subordination, whereas play is spontaneous and allows of idiosyncrasies and experimentation. From the biological point of view it is clear that human games cannot fully fulfil the function of play.

According to Groos there is no general "instinct to play"; it is enough to suppose that each type of playing animal has its inborn or instinctive system or pattern of predispositions towards particular types of adult activity, and that the young are peculiarly sensitive to liberating stimuli. Play implies not only susceptibility, but precocity and plasticity. It secures a certain freedom for initiative before habituation sets in. And, as has been said, this is of especial value when the adult life demands considerable versatility. In such cases, the animals that play best are also likely to work best.

If play is anticipatory of future work, the different kinds of play will correspond to the chief activities of adult life. Many forms of play, at its simplest, are of the nature of experiments in locomotion, as in aimless racing, rival jumping, riotous gambolling, and feats of climbing or of flying. Here one pictures the behaviour of lambs, kids, calves, young antelopes, and chamois, of foals, young squirrels, and young monkeys. On a second line is sham hunting, in which the young animal chases some moving object irrespective of all utility. A leaf blown by the wind or a ball of grass will pull the trigger as effectively as a small animal. The mother sometimes aids and abets, so here play coalesces with education. The kitten's play with the mouse, often absurdly misinterpreted as "delight in torture", is paralleled in many other young carnivores. It is justified in the present by the repetition of pleasurable excitement, and also in the future by the increased dexterity it develops. When the mouse-play is exhibited by cats of mature years, and apart from their education of their kittens, it is probably a relapse into youthful play, such as is illustrated less poignantly in some other adults. In lions the normal play-period extends for well over a year.

A third form of play is the sham-fight, familiar in puppies. It has been described among lions, tigers, hyænas, wolves, foxes, bears and other carnivores; among lambs, kids, calves, foals, antelopes, and other ungulates. It is also common among birds. Care must be taken to keep the sham-fight distinct from the combats of rival males, the first hints of which may begin early, as in bull-calves. And even apart from sex, it is not always easy to distinguish the sham-fight from serious combativeness. In his description of the behaviour of two young gluttons, Brehm says that nothing could be more playful; they were hardly at rest for a minute, but every now and then the note of earnest was struck. Very curious, considering the level at which they occur, are the so-called sham-fights which several good

observers have described among ants. There is energetic wrestling and the like, but no discharge of poison or actual wounding.

Perhaps one may recognise another type which may be called playful experiment, when animals test things, often pulling them to pieces; or test themselves, often performing interesting but useless feats; or test their neighbours, discovering how they will respond to sundry provocations. The difficulty is to distinguish these playful experiments from the ways in which many well-endowed young animals feel their way about in their environment. But Hamerton describes how his young goats would spend hours in jumping in and out of a basket, or would try to upset the artist by getting under his seat, or would tease the big dog to the limit of his endurance. Miss Romanes gave a circumstantial account of the experiments of her Capuchin monkey. "He is very fond of upsetting things, but he always takes great care that they do not fall upon himself. Thus he will pull a chair towards him till it is almost over-balanced; then he intently fixes his eyes on the top bar of the back, and, as he sees it coming over his way, darts from underneath, and watches the fall with great delight; and similarly with heavier things. There is a washhand-stand, for example, which he has upset several times, and always without hurting himself." For such behaviour as this it is difficult to use any other word but play, or to refuse to call it experimental.

Along this line the subtlest forms of play are found in apes, where experimenting may go far, and sometimes become sheer mischief. Thus we have watched an impish Indian monkey pulling tiles off an old woman's roof, and returning time after time, until one had to give up stoning him away, and leave the old lady to her fate. A chimpanzee often shows what looks like delight in being a tease, and an entirely useless activity may be repeated over and over again. The play may become a ploy. Thus a chimpanzee will entice a hen with bread and pull the reward away at the last minute, repeating the trick many times with evident gusto. Or it will attract a hen close to the cage and then give her a sudden poke with a stick when she is preoccupied with her food. Do not such monkey-tricks seem well up to the level of the practical joke, and sometimes even to "ragging"?

Of interest are those cases where playing—or something much like playing—is continued long after youth is past. This is familiar in the case of domestic dogs; but it is also exhibited in natural conditions, for instance by the otter. This extension of play may be sometimes associated with the mother's habit of playing with successive litters of young ones year after year. But this interpretation does not apply to all cases, for instance to the communal playing of full-grown penguins on the sea-ice. Thus Dr. Murray Levick has described the diving ploys in which the succession may be so rapid

"as to have the appearance of a lot of shot poured out of a bottle into the water". There is also a playful "porpoising", of which the chief feature is an exuberant leaping out of the water; and there is what is described as a game of "touch last" on the ice. A favourite activity was to go aboard an ice-floe till it would hold no more, and thus get carried by the tide to the lower end of the rookery, where every bird would suddenly jump off and swim back against the stream to catch a fresh floe and get another ride down. It thus seems impossible to restrict the idea of play to the youthful period.

But on the whole, play is a mode of behaviour characteristic of the youthful period of certain well-endowed animals; it is a precocious exhibition of activities which are more or less anticipatory of those characteristic of adult life, but are not yet in themselves of direct or immediate utility. Its biological significance is partly as a safety-valve for overflowing energy, partly as an early expression of imitativeness, and partly as a correlate of pleasant feelings, but mainly as an irresponsible apprenticeship to adult activities and as an opportunity for testing new departures, especially in habit. It has four chief forms: movement-play, sham-racing, sham-hunting, and experimentation.

Since these characteristics of typical play are tolerably well-defined, it is undesirable that the concept should be blurred by a vague and loose application of the term. The following restrictions may be suggested. (1) The term play should not be used for the idle movements of animals, such as insects and fishes, unless there is evidence that these are serving as an apprenticeship. Gregarious swimming on the part of cuttlefishes and fishes, gregarious flying on the part of insects and birds, may have no connection with migration, or mating, or the quest of food—indeed, no utility at all, and yet hardly deserve the name of play. Yet after all must there not be something of elemental joy in the midges' dance, or the marvellously sustained inter-swimming we have watched in Indian water-beetles?

(2) It is undoubtedly difficult to draw the line, but it seems well to try to distinguish from typical play all activities that are bound up with sex-display or courtship. For while these resemble play in being artistic and spontaneous expressions of individuality, they have an immediate outcome, though this may not be the conscious or subconscious purpose of the players. They serve to arouse sex interest and sex desire, whereas typical play has no such any immediate reward. If it seem impossible to draw a line between play and display, it may conduce to clearness if the word sex be used as a prefix. Thus, though W. H. Hudson said that he spoke advisedly of the fireflies' pastimes, it might have been clearer if he had spoken of their sex-flight. Similarly one might use some phrase, such as courting dance, for many of the extraordinary displays that birds make at the breeding season. Thus Mr. Hudson portrays the dance

of the Cock-of-the-Rock (Rupicola) of tropical South America. "A mossy level spot of earth surrounded by bushes is selected for a dancing-place, and kept well cleared of sticks and stones; round this area the birds assemble, when a cock-bird, with vivid orange-scarlet crest and plumage, steps into it, and, with spreading wings and tail, begins a series of movements as if dancing a minuet; finally, carried away with excitement, he leaps and gyrates in the most astonishing manner, until, becoming exhausted, he retires, and another bird takes his place." This strikes a note quite different from that which is clearly sounded in the races of lambs and kids, wild foals and asses, or in the various forms of "tig" and "follow my leader" that have been described among monkeys.

(3) We have suggested that the rubric of play should not include aimless adult movements, which may mean no more than a regularised social way of taking exercise, and should not include any form of non-utilitarian display that is connected with courtship, but another restriction may be proposed. It is part of the essence of play that it is not directly useful, but has a prospective value in educating efficiency. Yet not a few animals with abundant spare energy and initiative are known to indulge in occasional adventures which, though they can hardly be called other than playful, have no prospective meaning. Some of the experiments of apes, to which we have already referred, may illustrate this kind of behaviour, and should perhaps be called tricks rather than play. True play is characteristic of a species and is neither occasional nor individual. A naturalist relates that on one occasion, when botanising on the Alps, his dog ceased to follow him on the graduated path, and was seen to choose a more direct slope of hard snow. There he lay down on his back, folded his legs, and slid down like a toboggan. At the foot he looked up at his astonished master and wagged his tail! No conclusion can be based on single instances, however well documented, but we cite this case as an instance of probable misinterpretation. The observer supposed that the dog had thought out a short cut—an unnecessarily generous view; others have called it a piece of play. But the probability is that it was a casual adventure, such as may be reasonably put to the credit of many a well-endowed animal. But similar instances are known at much lower levels of intelligence. Thus Brehm describes the behaviour of the Spitting Fish, *Toxotes jaculator*, from the wonderland of Siam. Resting near the surface of the water, it fixes its eyes on an insect; and then, through the almost closed mouth, ejects a drop of water with fatal precision. Meissen, who kept two Jaculators in an aquarium, records that they became so tame that they would take food from their keeper's hand held four or five inches above the water. They became accustomed to the sight of strangers and "developed a game with them". "The first case was perhaps accidental; an observer

was shot right in the eye. But afterwards they practised on the nose, ears, and lips, and seemed to do so intentionally from a sheer sporting love of the thing." So Dr. H. M. Kyle reports in his *Biology of Fishes* (1926). Brehm continues: "With what certainty and celerity the fish had learnt to shoot can be judged from the fact, that even when one knew the shot was coming, at three feet away, one had no time to close one's eye". Of course a somewhat anecdotal report of this type must be critically scrutinised, but our point here is the general one that the rubric of "play" should hardly be extended to cover instances of clever individual adventure, however playful these may seem. The ecological concept of animal play is most useful when it is employed in the strictest sense, as already defined.

INDUSTRIES OF ANIMALS

In summer man thinks of holidaying, even when he can't; but in Wild Nature summer is the season of intensest industry. All over the green earth the chemical factories are silently busy, using the red-orange-yellow rays of the sunshine as the power by which they split carbon dioxide, and build up sugars and still more complex and valuable carbon-compounds. As the plants make far more foodstuff than they need for themselves, there is a surplusage for the animal world; and as the carnivores depend on the herbivores, we may justly say that all flesh is transmogrified grass. Thus summer is the time of greatest animal industry *because* there is a maximum of energy available for transformation.

Animals that were feeling their way in spring are able in summer to strike out on their own; and work is the natural expression of vigour. It is as natural as play. Happiness is in no small degree the reflex of harmonious functioning; and wholesome work is its own reward. As Luther wisely said: "When I rest, I rust." As George Meredith puts it: "Behold the life of ease, it *drifts*."

Another reason for the industry of summer is to be found in the tonic power of the sunshine, when there is not too much. And we must not forget another point of view, that many kinds of animals must be industrious in summer if they are to keep alive during the winter. In other words, in the course of ages there has been an elimination of the sluggish and a fostering of the industrious.

It is not as if animals could look ahead with a thrifty eye, but the fact remains that animal industry has often "survival value". The perennial beehive is a good example, in contrast to, let us say, the community of Humble-bees, from amid which only the young queens manage to survive the winter. And so there are permanent ant-hills, perennial because of their stores. We are not unaware of the seamy

side of the ant régime, but the instinctive industry displayed is incontestably admirable! "Go to the ant, thou sluggard; consider her ways and be wise: which having no guide, overseer, or ruler, provideth her meat in the summer, and gathereth her food in the harvest."

The industry of animals is largely concerned with bread-and-butter, but it has also in many cases to do with making shelters and nests. On the whole, life swings on two pivots—"hunger" and "love", both in inverted commas. As Goethe said long ago for mankind, so we may ask and answer for animals: "Why do the people so strive and cry? They will have food and they will have children, and they will bring them up as well as they can." Such is life, through and through.

Since industry has much to do with exploiting the resources of Nature, it is not surprising that there should be among animals the counterparts of human activities. Thus there are all sorts of pre-human huntsmen: quick hunters, like fox and eagle; stealthily slow hunters, like the wild cat and the python; lurkers like the young ant-lion, buried up to the jaws at the foot of his pit-fall in the sand, or like the young tiger-beetle who sinks a shaft and waits within it until an inquisitive ant steps on his head, which serves as the trap-door. Then with explosive violence the head is jerked upwards and backwards, and the victim is crushed against the edge of the shaft. Among spiders may be found the past-masters in snaring.

Some animals hunt alone, like the otter and the subterranean mole; others hunt in packs, like the wolves in winter. Some hunt in daylight, like most of the birds of prey, and some in the dark, like the owl and the hedgehog. Hunting fades into fishing, and again we have the swift fishers, like seals and otters, and the slow fishers, like the herons waiting pensively by the side of the lake. Pelicans make a living seine-net, driving the fish before them as they wade inwards in a crescent towards the shore. Some of the caddis-worms make the neatest imaginable bag-nets by which they catch what the stream brings down. Some fishes in the dark abysses seem to use luminescent lures.

The discovery of the underworld by earthworms to begin with, and later on by centipedes, millipedes, sexton beetles, blindworms, burrowing snakes, moles, and other tunnelling mammals, has implied much in the way of mining; but the analogy rather breaks down, since the animal miners do not bring wealth to the surface as men do. And even when we recognise that earthworms manure the soil with leaves, and plough it very effectively, they are not agriculturalists in the sense of making things grow. Even the Agricultural Ant of Texas is treated rather as a joke for tourists.

There is no doubt, however, that the leaf-cutting ants cultivate in their underground cities a unique fungus, grown on green beds of

chewed leaves, and that this forms their sole food when they are beneath the surface. So there are beetles that grow an "ambrosia" mould and are indubitable cultivators; and the keeping of aphides as cows is well-established for several species of ants. Recent work has shown that day after day the same ant may bring the same aphis out of the stable in the morning, deposit it on the pasturage of a branch, milk it during the day, and take it home in the cool of the evening! Is there not here more than the beginning of a sense of property?

We need not continue the story, for our simple point is to show that the correspondence between animal and human industries is real, not fanciful. The parallelism is a very interesting one, and should be followed by observation and by reading.

CHAPTER VIII

GREAT STEPS IN ORGANIC EVOLUTION

THE ASCENT OF LIFE, OR THE FAUNA AND FLORA OF SUCCESSIVE GEOLOGICAL AGES

IN the ecological chapter an outline was given of the spatial distribution of organisms in various regions of land and sea; we turn now to the distribution in *time*. Each geological age has had its character-

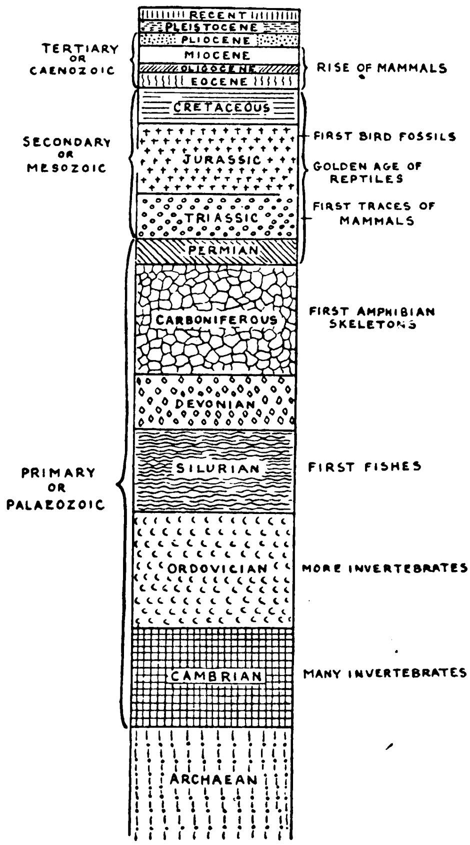


FIG. 137.

Diagram showing the Successive Geological Formations composing the Crust of the Earth. The later periods are perforce exaggerated in thickness in proportion to the much longer earlier periods.

istic plants and animals, and the succession has continued for about a thousand million years—more or less—on the latest calculation based on the combined estimates of geologists and radiologists.

The largest fact disclosed by the study of geological distribution

is indicated by the popular phrase "The Ascent of Life", or "The Advance of Life", that in the course of the geologic ages there has been a gradual emergence of more and more highly differentiated and integrated organisms. The "geological record", albeit far more than half-concealed in the fossil-bearing rocks, shows that there was an Invertebrate fauna for long ages before there were any Vertebrates, that Fishes thronged the seas long before the pioneering Amphibians began to struggle on to dry land towards the end of the Devonian Period. For a prolonged period, from the Permian onwards, the highest backboned animals on the earth were Reptiles, of all sizes and sorts, and each expressing in their own way varied possibilities of locomotion—first creeping and then running on the solid ground; swimming in pool and river; and even thence returning to the sea, or parachuting and even flying in the air. Their alternatives doubtless descended to burrowing, and rose to tree-climbing as well, as a good many living forms of reptiles still do. But of burrowing and tree-climbing reptiles there are no fossil remains. Only when the Reptiles were passing their Golden Age do we find sparse representation of primitive Birds and pigmy Mammals. The large fact is that for millions of years there was a growing dynasty of Reptiles, with as many modes of life, or "adaptive radiations", as we see in the Mammals of to-day.

What is true of the great classes of Vertebrates, that the higher ones were latest to appear, holds true of the orders within these classes. Thus we find simple and primitive mammals long before the appearance of specialised orders, such as Cetaceans; while of the extremely differentiated bat-tribe there are few fossils and none primitive. Similarly within particular orders; thus the earliest representatives of the elephants, or of the horses, were much more generalised than those that succeeded them, or are surviving to-day. As ages passed there was, on the whole, a gradual increase in differentiation and integration at most levels of life, except where racial senescence or retrogression set in.

Certain as is the Ascent of Life from age to age, three saving clauses must be noted. (*a*) In the earliest period with abundant fossils, that known as Cambrian, most of the great groups or phyla of Invertebrates are already represented. This at first sight surprising fact becomes intelligible when we recognise that there had been a very long history before the Cambrian—a history of which there are no records at all in the Archæozoic rocks, and not more than a few, and these very fragmentary and puzzling, in what we thence call the Proterozoic. In short, there must have been a prolonged Pre-Cambrian evolution, both for plants and animals.

(*b*) In the second place it must be recognised that amid the general advance there have been particular retrogressions. Evolution may anywhere proceed downwards as well as upwards; and retro-

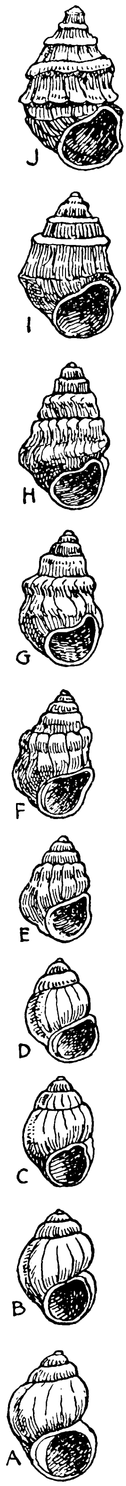


FIG. 138.

Evolution Series of Species of the Water-snail, Paludina, from the smooth *P. neumayri* (A), the oldest form, to the rough *P. hœrnesi* (J). From Neumayr.

gressive lines are to be found to-day, especially among sedentary forms, such as barnacles and Tunicates, among easygoing forms, such as Tardigrades and blindworms, and among parasitic forms, such as tapeworms and lice. Similarly in the geological record; among types preservable as fossils there are many instances of reversed

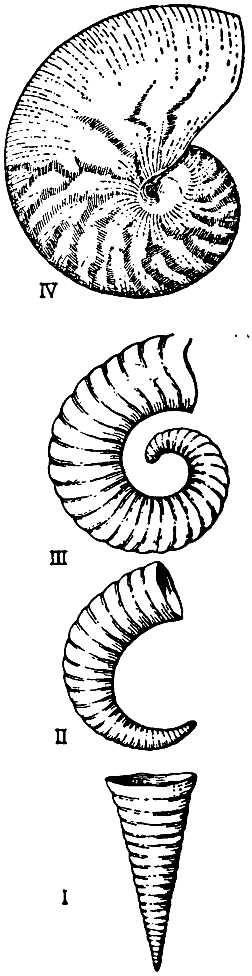


FIG. 139.

An Evolution Series of Nautiloid Cephalopods. After Lull. I, a straight-chambered Orthoceras type; II, a slightly curved Cyrtoceras type; III, a more curved Gyroceras type; IV, the Nautilus type, the only survivor in this series.

evolution, as when some of the spirally coiled Cephalopods, on both Nautiloid and Ammonoid lines of evolution, are succeeded by related forms which are loosely coiled, and these again by slightly curved or even straight forms, which have returned to the oldest and more primitive type of shell.

(*c*) It is necessary to make a distinction between increasing

intricacy in structural detail and progressive advance to some new level. Many animals which occupy a low position on the general scale of being are extraordinarily complex. This is well illustrated by the exquisite intricacy of Radiolarians among the Protozoa, and again of many Sponges, such as the well-woven Venus Flower-Basket (fitly named Euplectella), or the Glass Rope Sponge (Hyalonema). So again among many of the Corals (such as the Blue Helioporas), and similarly among Polyzoa, Echinoderms, and so forth. Yet despite all their complexity in detail, none of these types reach the higher level of main organisation represented by such familiar animals as segmented worms. So among ancient fossils, like the sponges, etc., aforesaid, there is often a much greater intricacy of structure than in forms which must yet be ranked far higher, when judged by the standards of essential differentiation of structure and integration of function. Thus even successful types, well adjusted to their environment, may eddy rather than progress in their evolution, with the intrinsic variability of the organism finding its expression in detailed intricacy, often of great beauty, rather than in raising the type to a higher functional and structural level. We may instance, for this eddying development, many extinct Sponges, Corals, Crinoids, and Lamp-Shells. Or again after the Ammonite type had reached its general acme, it thereafter specialised into detailed complexity of the foldings of the suture-line, where the successive septa are united to the surface of the shell. In these ornamented sutures, of great value in classification, we can see little or no functional value. The same detailed complexity is well illustrated by the fantastic individuality of armature indulged in by not a few Cretaceous Dinosaurs. Or again, while we can see substantial use in the complex folding of the elephant's molar teeth, surely the like in certain of the Carboniferous amphibians, appropriately termed Labyrinthodonts, shows an elaboration which suggests a veritable superfluity of eddying.

Another large fact which a survey of the geological succession at once discloses is the frequent extinction of highly developed types. We can readily understand the elimination of the earlier stages in any continuing evolutionary series, but it is surprising to find the extinction of entire races, so thorough that their lineage came to its end. From the generalised crocodilians of the Triassic and Jurassic Periods there arose a number of more specialised genera, which have long since become extinct; yet the race of Crocodilians is still well-nigh world-wide—witness the Crocodiles of Africa, Tropical America, West Indies, India, Malay, and North Australia; the Alligators of the Southern States and of China; the Caimans of Central America and South America, and the long-snouted Gavial of India.

This is an instance of the obliteration of the earlier stages in an evolution series, with survival of well-adapted ones; and the same

may be said of other cases where the evolutionary lineage is well known, as of horses, elephants, and camels, each illustrating the transformation of a race with a survival of efficient living representatives. Yet there are many cases where a large group has become wholly extinct, leaving no direct descendants, as is notably the case with the probably pelagic Graptolites, which were so common in Silurian seas. They are generally regarded as related to the Hydrozoa of to-day, but they cannot be referred to any division of that large and diverse class. Some of them were probably slow swimmers, while others were attached to the drifting seaweeds of a Silurian Sargasso Sea. But the point is that Graptolites represent a "lost race"; they became extinct in the Lower Carboniferous, and they are not known to have any persisting relatives.

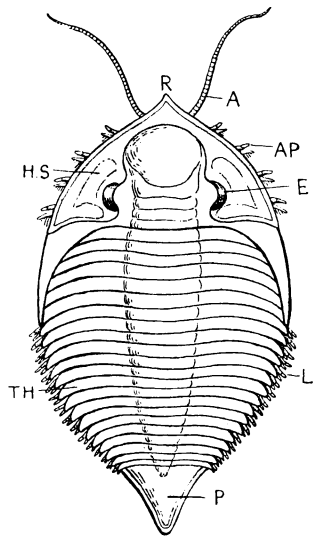


FIG. 140.

A Trilobite, an extinct type of Arthropods, lasting from the Cambrian to the Permian R, rostrum or beak; A, antenna; HS, head-shield; E, eye; AP, projecting appendages; TH, thorax; L, thoracic limbs; P, tail-piece or pygidium. After Beecher.

Similarly, the ancient Trilobites (Cambrian to Permian), their allies the Eurypterids (Silurian to Permian), the two classes of Echinoderms known as Cystoids and Blastoids, and the whole race of Ammonites, are all lost races. The series of Nautiloids, parallel to that of Ammonites, but not nearly related, is represented to-day by the Pearly Nautilus, one genus with only four species.

So among backboned animals there are four or five orders of ancient reptiles that have no living representatives; and while it may be objected that birds and mammals seem to have evolved from two stocks of extinct Dinosaurs, whose blood has therefore not ceased to flow, it is only necessary to mention the Pterodactyls,

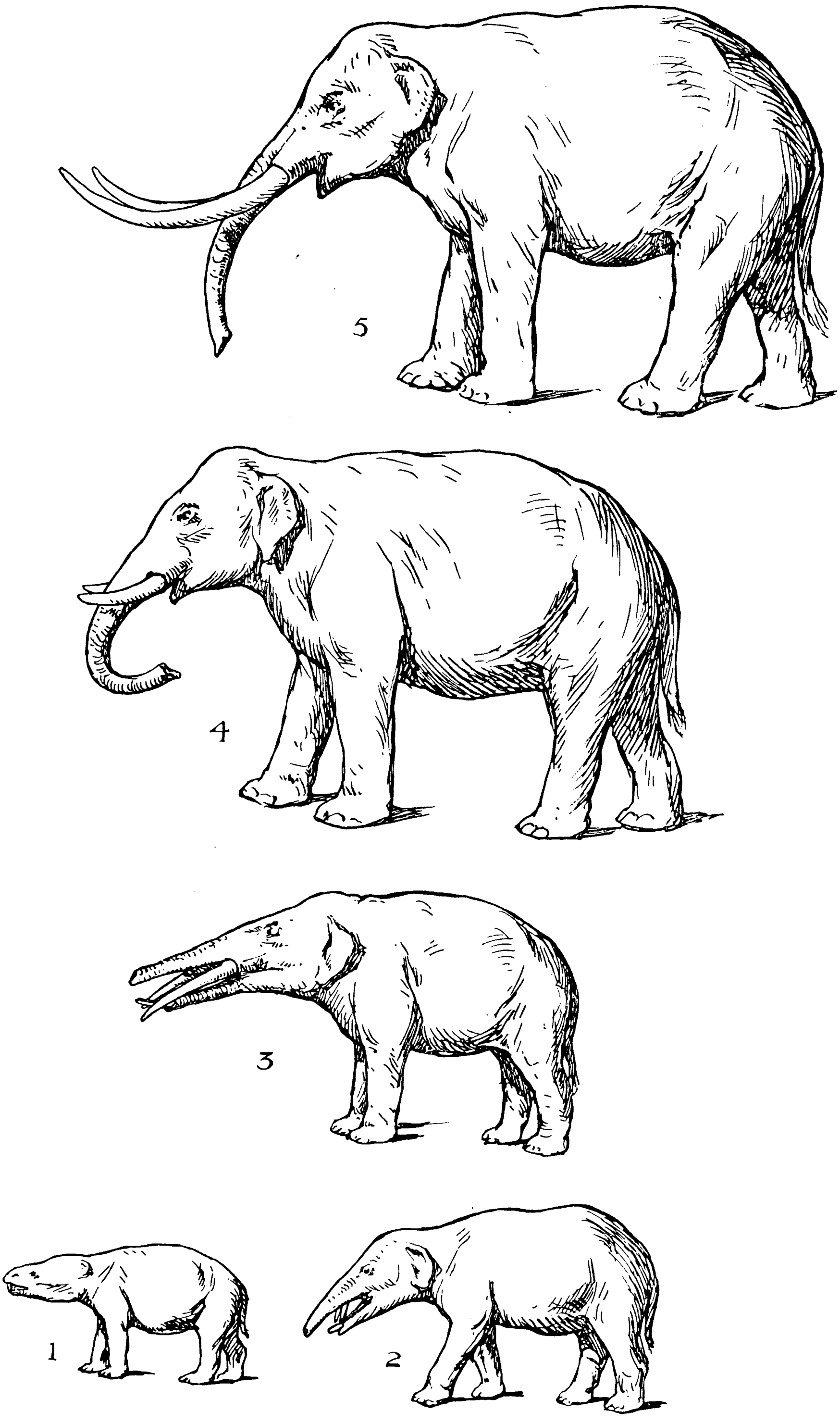


FIG. 141.

Reconstruction of a Series of Types in the Evolution of the Elephant. From models. After Lull. 1, Mœritherium; 2, Palæomastodon; 3, Tylophodon; 4, Mastodon; 5, Elephas.

veritable flying dragons, as instance of a remarkable order which has had neither continuance nor successors. Similarly, some of the old orders of mammals, such as the huge hoofed Amblypods of the Eocene, seem to have disappeared without leaving any near relatives, while many comparatively primitive mammalian types still go on.

What can be said in regard to the causes of extinction? In the first place there is little to suggest that sudden extinction has often occurred, save in recent times, when man has intervened unconsciously or ruthlessly. Thus the European Bison has ceased to be a wild animal since the Great War; the till lately multitudinous Passenger Pigeon disappeared in a very short time, even within living memory; but the rock record of race extinctions points almost always to a gradual waning. Local floods, earthquakes, volcanic eruptions, landslips, and the like may have rapidly exterminated species and even genera; herbs and trees alike seem peculiarly liable to destruction by mould or insect enemies; yet on the whole races seem to die out but slowly. Three suggestions may be offered. (*a*) In many cases the waning away of an order, or even of a class of animals, may have been associated with the appearance of some formidable new competitor; thus cuttlefishes would tend to exterminate Trilobites, and Ichthyosaurs in their turn would thin out the cuttlefishes, whose beaks often crowd their stomachs. (*b*) At this day many highly specialised types are unable to adjust themselves to what seem to us slight changes in their environment, and this may have been even more true amid the drastic changes of the past. Thus Marsh has suggested that some of the magnificently built extinct reptiles might have for their epitaph: "I and my race died of over-specialisation." (*c*) Do not a good many extinct types seem to have fallen victims to their own constitutions? Witness numerous reptiles, surely overgrown in body beyond their brains, like the colossal *Diplodocus carnegii*, which even in cast is so striking an attraction of the British Museum, and some Mammals also, huge and sluggish, like Megatherium, and even too calcareous, like the Glyptodon, wellnigh stone-coffined—all, in short, in some way too extreme. Among backboned animals, endocrinal glands may have broken down before some difficult problem of bodily regulation, or may by excess of function have hurried the creature along some fatal path. In gigantism and in nanism, both difficulties may operate in varied proportion, for such cases recall the vivid phrase of Lucretius, of animals "hampered in their own death-bringing shackles".

PERSISTENT TYPES.—In contrast to the Becoming and Disappearing (*Werden* and *Vergehen*), which is characteristic of the long-drawn-out history of living creatures, and in peculiar contrast to the organic flux which is exhibited to-day in certain well-known

mutant types, as Morgan has so well shown for the Fruit-fly (Drosophila) and De Vries for the Evening Primrose (Œnothera), there are some types which have persisted in much the same state of being for inconceivably long ages. Thus the lamp-shell (Lingula), which still flourishes to-day, projecting in multitudes from the mud of shallow waters in the Indian Ocean, was established as a genus (if not even species?) hundreds of millions of years ago in the Silurian Period. There are other long-lived Brachiopods, such as Discina, Crania, Rhynchonella (all three from the Ordovician onwards), and Terebratula (from the Devonian).

The Pearly Nautilus is the only living Cephalopod that shelters itself inside a chambered shell, for the unchambered shell of the Paper Nautilus (Argonauta) is formed by the female only, and is more of a cradle for the young than a house for the adult. Now the Pearly Nautilus, represented to-day by four species off Sunda and Fiji Islands, dates from the Jurassic, and has near relatives much more ancient.

The Queensland Mudfish (Ceratodus) which has its swim-bladder transformed into a lung, was widespread in the Triassic; and about the same time there arose the rare lizard-like Sphenodon, still holding its own (under protection) in two or three small islands in the Bay of Plenty off the coast of New Zealand. It is the sole survivor of its order of Rhynchocephalia, and so an extreme instance of what Darwin called "living fossils".

These are a few outstanding instances of persistent types, but their frequent citation by palæontologists is apt to give rise to the misconception that long persistence is rare. As a matter of fact there are numerous cases of long persistence. Thus there are some very ancient types among Foraminifers and Radiolarians; among worms, e.g. Serpula, so common on shells; among minute crustaceans, e.g. Cypridina of salt water and Pontocypris of fresh; among bivalves, e.g. the hammer-shell Avicula; among Gasteropods, e.g. the not infrequent Chitons, and, most familiar of all, the common limpets of our rocky shores, whose type, or even genus, has continued since Silurian times. There are also doubtless numerous persistent types which cannot yet be demonstrated as such, owing to our still so limited exploration of the geological record, itself so imperfect at best.

How are we to explain the persistence of the same type, and without appreciable change, for it may be millions of years? These types have proved themselves of normally sound constitutions, effectively adjusted in adaptation to some fairly persistent environment, and hence cumulatively stabilised in their heredity. Given such organisation in harmony with its long-enduring conditions of life, what reason can there be for change? A life-equilibrium has been reached, and the organism holds fast accordingly; its tendencies to variability have fallen into abeyance.

PALÆONTOLOGICAL SEQUENCE.—After this glance at these general problems, we must pass to what cannot be more than a palæontological outline of the successive geological periods, indicating briefly (*a*) the outstanding features of the physical environment, including, of course, the climate, (*b*) the dominant characteristics of the fauna and flora, and (*c*) any momentous new departure that was distinctive of the time.

We have shown (Fig. 137), in a scheme which cannot be drawn to scale, the successive geological periods, as represented by the strata building up the earth crust—strata which would form a thickness of about sixty miles if they all occurred in completeness at any one place.

ARCHÆOZOIC.—Living creatures were not possible until the earth's crust had cooled into firmness, and until there was abundance of water in a liquid state. In other words, the story begins with a "lithosphere" and a "hydrosphere", and to these must be added a primitive atmosphere. In this there was little free oxygen, and not very much nitrogen; the bulk of the primitive atmosphere consisted of carbon dioxide and water vapour. When life began, perhaps under the influence of sunlight radiating through the cloud-curtain, carbon dioxide began to be utilised as a source for the synthesis of carbon-compounds, and free oxygen passed into the atmosphere, which thus became increasingly breathable. The quantity of oxygen has steadily increased since the time of the first atmosphere, but though much is used up in oxidation processes in rocks and minerals, and much also in the respiratory processes of animals, this loss is more than met by the liberation of oxygen from green plants. And while carbon dioxide becomes temporarily fixed in plants and more firmly in carbonates and the like, there is a re-supply from volcanoes and hot springs and the breath of animals. Nothing is known of living creatures in this preparatory era, but their presence is indicated by beds of graphite and so forth. It was in all probability the era of Unicellular Life.

PROTEROZOIC.—The first undeniable remains of organisms occur in the Proterozoic Era, sometimes called the later Pre-Cambrian. As the study of the very early strata becomes more and more penetrating, the list of Pre-Cambrian fossils grows. They include marine Algæ, some Protozoa (Radiolarians), and some not very satisfactory tracks of burrowing worms. It may be thought of as the era of the emergence of the simpler Invertebrates, and it was of long duration. Towards its beginning and ending there were Ice Ages, and its continuance was punctuated by volcanic eruptions and lava flows and vast surface disturbances, such as the "Grand Canyon revolution".

CAMBRIAN.—The upheavals and accumulations which marked the later Proterozoic Period continued in the Lower Cambrian, which

may be thought of as the time when many, if not most, of the classes of marine Invertebrates were established, such as sponges, some corals, Graptolites, even jelly-fishes, starfishes, crinoids, trilobites, and lamp-shells. It is in Cambrian rocks that we find the first convincing evidence of the locking up of carbonate of lime in substantial skeletons, such as those of Crinoids—a process interesting in itself and of great importance to the palæontologist, since it means the occurrence of well-preserved fossils. It was a habit that grew upon certain animal types, for some that are still soft-shelled in the Cambrian are very calcareous in the mid-Ordovician.

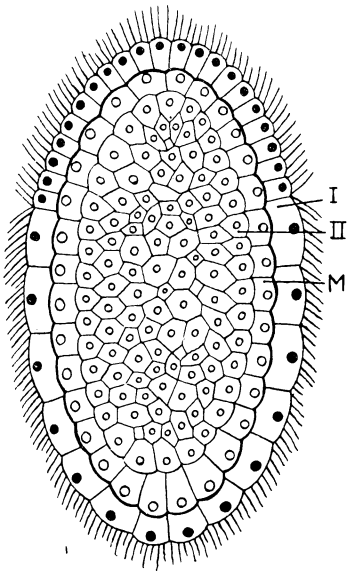


FIG. 142.

An Orthonectid, one of the simplest multicellular animals or Mesozoa. I, ciliated outer layer; II, the internal mass of cell; M, an intermediate layer. The small circles are the nuclei of the cells.

ORDOVICIAN.—It is from mid-Ordovician (= Lower Silurian) deposits that the first Chordate or Vertebrate fossils are known, but the probability is that this great phylum began earlier; perhaps, as has been suggested, in a time of quick movement of water which might serve as a stimulus to some vermine ancestors to move energetically with, or (perhaps more promisefully) against the stream. The earliest Chordate remains belong to the order of Ostracoderms, sluggish pre-fishes, probably off the main line of Vertebrate advance.

More impressive at the time must have been the Cuttlefishes or Cephalopods, representing the highest class of Molluscs, and not in any way related to true fishes. These Nautiloid Cephalopods are first known from the Cambrian, but they became dominant in the

Ordovician and Silurian seas. They probably fed in great part on Trilobites.

Another feature of the Ordovician Period was the first appearance of plants higher than seaweeds, some of them perhaps from marshland, with hints of wood-vessels.

SILURIAN.—The later part of the Silurian Period was marked by uplifting crust-movements and by aridity, which was continued into the Devonian. With the cumulative drought may be associated an early colonisation of the dry land, and we think of the Silurian as the time of the beginning of a terrestrial fauna. Thus there is a primitive fossil Millipede, Archidesmus, from the Scottish Lower Silurian, which perhaps deserves to be called the oldest known thoroughly terrestrial animal. It does not show the doubling of the body-rings that marks ordinary Millipedes. Two primitive scorpions are also known from the Silurian, but their surroundings, as well as some structural details, suggest that these had already become *secondarily aquatic*. They had probably relapsed from terrestrial ancestors of yet earlier date. Also noteworthy in the Silurian seas were the pioneers of the King-crab race, now represented by the single genus Limulus. The seas were richly peopled, and there was an especial abundance of corals. In fresh waters there was probably an emergence of pioneer Lung-fishes.

DEVONIAN.—The onset of aridity in the late Silurian abated through a great part of the Devonian Period, yet seems to have been characteristic throughout, and even to have risen again to great severity towards its close. Aridity was the climatic keynote; hence, while we mostly think of the Devonian as above all an age of fishes, a yet stronger interest to the evolutionist is in the way the aridity seems not only to have limited animal life on land, but also largely to have stimulated it. For it is from this period that we have to date the peculiarly important advance beyond ordinarily gilled fishes to also lunged ones, notably the Dipnoids, and even the emergence of Amphibians. So our familiar experience of gilled tadpole changing to well lunged and even vociferous frog is a veritable condensation of the main advance of these Devonian times.

The dry Devonian climate reduced the extent of rivers and lakes, and the frequent drying-up of pools must have prompted, indeed often compelled, the lunged fishes to make the best of the drying land, and to use their simply shaped fore and aft paired fins for support and locomotion. Moreover, the aëration of fresh waters must have been lessened by lack of streams, and this would favour lung respiration by gulping air at the surface, as Polypterus has still to do. Thus it is not surprising that the first recorded lung-fish appears in the Lower Devonian, and that the first digitate footprint, made by the pioneer Amphibian, *Thinopus antiquus*, should date from the Upper Devonian. The original of this most eloquent of tracks

is to be seen in the Peabody Museum at Yale. It is the oldest known fossil footprint, and, so far as we know, it marks the adventure of the first backboned animal upon the dry land his progeny were to colonise. There are marks of two well-developed toes, of a budding third, and a hint of a fourth; and the whole imprint shows a close resemblance to that of a stage in the development of a newt's foot.

The freshwater fishes of the Devonian Period were either Lung-fishes (Dipnoi) or well-armoured Ganoids, of which a few genera still survive, especially of the Crossopterygian or "fringed-fin" order, such as the well-known fossil Holoptychius. The order has representatives to-day in Polypterus and Calamoichthys, and it is interesting to notice that these best of all point the way, and this very distinctly, towards Amphibians. Thus the air-bladder of Polypterus is a paired structure and is filled with dry air gulped in at the surface of the stream; and although this quasi-lung lies dorsally, it arises, as in all lunged animals, from an outgrowth on the ventral surface of the gullet, with which its air tube (answering to our trachea) remains connected. The larva of Polypterus is remarkably tadpole-like, for it has feathery external gills, and also a glandular attaching organ just behind the mouth—both very familiar features of the young tadpole. But our present point is simply that there were in the Devonian period various freshwater fishes allied to Polypterus, which most zoologists regard as ancestral to Amphibia, though a few still hold by the Dipnoans. Also characteristic of freshwater sedimentary rocks of Upper Silurian and Devonian Age are certain very primitive limbless types included with difficulty among fishes, such as Pterichthys and Pteraspis.

Some of these Ostracoderms or Hypostomes, such as Pteraspis and Cephalaspis, are so beautifully preserved in Norwegian and Spitzbergen strata that there are indications of even the principal nerves and blood-vessels of the head! They were pioneer Vertebrates, below the level of true fishes, probably more nearly related to our hags and lampreys.

The marine fishes of this Devonian Period were chiefly of the shark type, and these were so dominant that the descriptive title "The Age of Fishes", often applied to the Devonian Period, is well justified by them, as well as by the numerous freshwater forms, which seem to have been even more successfully progressive. In connection with Devonian fishes it is of interest to recall Hugh Miller's *Old Red Sandstone*, which was one of the rare instances of a technical book winning a large audience by the force and picturesqueness of its vividly visualising style. It dealt largely with the author's discoveries of "Old Red" fishes of the Cephalaspid order —pre-fishes as many have come to regard them; and it was for one of these strange types, limbless, sometimes jawless, that Agassiz, proposed at the British Association Meeting in 1840, the technical

name *Pterichthys Milleri*, and said of Hugh Miller, whom he was scientifically honouring, that he "would give his left hand to possess such powers of description as this man".

Apart from the still shadowy pioneer Amphibians that made the digitate footprints of the Upper Devonian, we do not know from that time any animals *higher* than Fishes, but their very existence would be enough to show that the seas were rich in *backboneless* animals. Indeed, we find representatives of all the classes of Echinoderms, many Lamp-shells or Brachiopods, and thousands of species of Molluscs of all sorts, including Ammonoids and Nautiloids. There were still many Trilobites, and increasing legions of Crustaceans; not to speak of lower Invertebrates. In short, there was a rich Invertebrate fauna in the Devonian seas. The freshwater fauna was naturally poor, since doubtless subjected to severe elimination during the prolonged periods of aridity. On land there were already Myriopods, and, at a still higher level, scorpions, but as yet no insects.

In regard to plants, the outstanding fact is that the Early Devonian is the Age of the oldest terrestrial flora of which we have any adequate knowledge. This flora included many simple plants, best represented in a bed discovered at Rhynie in Aberdeenshire by Dr. Mackie in 1913; and it is difficult to refer these to any existing class. They are unique as well as primitive. But among other archaic flowerless types of the Devonian, there are some striking anticipations of higher grades. Thus the remarkable *Palæopitys Milleri*, discovered to his joy by Hugh Miller, who, as an anti-Evolutionist, welcomed, in his *Footprints of the Creator* (1847), the obtrusion of "a cone-bearing tree" long before it was theoretically due! "This certainly", he said, "is not the sort of arrangement demanded by the exigencies of the development hypothesis." It will be evident from the dates that Hugh Miller was here counterblasting Robert Chambers's *Vestiges of Creation* (1844), and not Charles Darwin's *Origin of Species* (1859). The possibility that this middle Devonian Palæopitys may represent the earliest Gymnosperm, does not raise any great difficulty to the modern palæo-botanist; for Lycopods were abundant within the millions of years labelled Devonian; and the gap between them and the Conifers is not so great as it seems at first sight.

In the Upper Devonian there was also a good representation of ferns, and amid this predominantly cryptogamic and seedless vegetation, some seed-producing Gymnosperms raised their heads in the Upper Devonian. This beginning of Seed-plants was one of the most momentous events in evolution.

In the Days of the Dinosaurs.—Let us relieve a condensed narrative with a more synthetic picture, which may also be of use as a recapitulation. Towards the end of the Devonian or Old Red

Sandstone Period in the history of the earth, perhaps 300,000,000 years ago, one of the greatest steps in evolution was taken, for certain pioneer amphibians clambered out of the pools and began the colonisation of the dry land. Of the earliest of these we can say little, for only their footprints are left; but their successors in the next great period, the Carboniferous, can be reconstructed from their fossil remains, and it is safe to say that they were successful, promiseful, and often large in size. Amphibians as big as donkeys frequented the dense and damp Carboniferous forests, whose remains we call Coal Measures. To an extinct order of pioneer Amphibians, known as Stegocephali, the great class of Reptiles must be traced; and this momentous emergence probably occurred in Carboniferous times. In any case, before the close of the next geological period—the Permian—many of the orders of Reptiles were already established. Yet it is to the subsequent Mesozoic Era (Triassic, Jurassic, and Cretaceous) that the term "Age of Reptiles" is usually and deservedly applied, and among the terrestrial Reptiles the Dinosaurs were the most dominant. It should be noted that just as the mammals of to-day include aquatic types like whales, aërial types like bats, amphibious types like otters, and so forth, so in Mesozoic times there was a similar diversity among Reptiles. The struggle for existence was keen and the will to live was strong, so there were many tentatives as regards haunts and habits. Besides the terrestrial types that crawled, or walked, or ran, there were aquatic, aërial, and amphibious forms. In addition, there were probably arboreal climbers and subterranean burrowers, but animals of the trees and of the underworld are not readily preserved as fossils.

With a pedigree dating back to the Carboniferous, and gathering strength to the Permian, the great order of Dinosaurs began in the Middle Triassic, perhaps in Europe, where their earliest remains are found. They spread as conquerors all over the world, dominating the earth for millions of years, and then waned away at the close of Cretaceous time. Can we form any picture of the kind of world they lived in?

Contrary to an earlier view, the general opinion of modern geologists is that the position of continental and oceanic areas has been much the same throughout geological time. But there is little doubt that the continents were once much larger and the seas much smaller than they are to-day; and there is no doubt that there have been from time to time vast bucklings of the earth's surface, great elevations here and depressions there, besides drastic changes of climate with far-reaching influences on plants and animals. Towards the end of the Carboniferous time there were enormous uplifts, such as that now represented on a reduced scale by the Appalachian Mountains in North America; and associated with this elevation of vast areas there came *aridity*. A widespread drought was probably

the spur that led to the evolution of Reptiles from Amphibians. For water basins were scarcer, and it became more difficult to have gill-breathing larval stages living an aquatic life. Reptiles arose in an age of aridity, and some of the fossils are betwixt-and-between forms, in regard to which it is difficult to decide whether they should be called Reptilian or Amphibian.

But in the Permian Period another great change came about, especially in the Southern Hemisphere, namely *glaciation*. It is believed that this was more intense and extensive in the South than were the recent (Pleistocene) Ice Ages, during which, in spite of terrific elimination among animals, tentative men were able to get a footing. So, millions of years previously, the Permian glaciation may have been a spur to the evolution of Dinosaurs.

Widespread drought would intensify the struggle for existence, and would put a premium on swiftness of locomotion; and this in turn would imply a rise of body-temperature owing to the stronger development of heat-producing muscles. But the setting in of intense cold would raise the new difficulty of conserving sufficient heat to keep vital processes agoing. For it must be remembered that Reptiles have not risen above cold-bloodedness, that is to say, the approximation of internal to external temperature. Only in Birds and Mammals do we find warm-bloodedness, that is to say, the power of conserving a constant body-temperature, day and night, year in and year out.

Thus we have the puzzle of the Dinosaurs evolving at a time when there was great aridity in some areas, and great cold in others, and when there were still more difficult places where both conditions obtained. Perhaps the muscular development and activity of Dinosaurs gave them a heat-supply large enough to do something to compensate for the loss to the cold air; perhaps the Dinosaurian muscle produced more heat than that of modern reptiles, for "all flesh is not the same flesh", and one recalls that even the tunny-fish has considerable bodily warmth; perhaps the external armature of scales and scutes, sometimes very substantial, helped to conserve the precious animal heat; perhaps some of the Dinosaurs lay low when the worst came to the worst, becoming comatose in winter as many living reptiles do. There are many perhapses, and the riddle is unread; but we must think of the Dinosaurs establishing themselves in a world which was in part dismally arid and in part glacially cold. Prof. R. S. Lull makes an interesting suggestion: "Possibly the early dinosaur-like forms which dwelt within the influence of the Permian cold became the birds, while those beyond its influence remained dinosaurs, and as such were destined to dominate the lands as no creatures before them had ever done." And another of this thought-provoking palæontologist's suggestions is the influence of aridity in evolving bipedal progression, which many Dinosaurs

certainly exhibited. The connection may be that long hind legs help in rapid locomotion, as is well illustrated by the Collared Lizard of Australia, Chlamydosaurus, which seems to be at present achieving considerable success as a swiftly moving biped. As many of the Dinosaurs were carnivores, it is also possible that the bipedal habit was associated with the specialisation of the fore-limbs for capturing prey.

Of the Triassic times, when Dinosaurs had become firmly established, it may be said that arid conditions continued over immense

FIG. 143.
The Australian Collared Lizard, Chlamydosaurus. After Saville Kent. This reptile is essaying a bipedal mode of progression.

areas. In the Jurassic there was an oscillation to humidity, and many of the Dinosaurs, sometimes toothless, often huge and sluggish, fed on the rich vegetation around the swampy shores of shallow seas. Towards the close of the Jurassic there seems to have been another great uplift, probably imposing a check on some of the Dinosaur types, but in the Cretaceous times there were again extensive amphibious habitats, and the Dinosaurs reached their climax of size, success and specialisation—the last probably continued beyond the limit of safety. For the end came suddenly, as geologists count sudden, and no member of all the hosts of Dinosaurs survived the close of the Cretaceous. The causes of their extinction are uncertain,

but there was a lowering of temperature toward the end of the period, which may well have been fatal. Moreover, there is evidence that the low-lying coastal lands underwent natural drainage, so that the old amphibious haunts disappeared. Over-specialisation probably counted for a good deal, but it looks as if climatic changes had been potent factors in the disappearance, as in the emergence, of the Dinosaurs—in many ways the most remarkable group of animals that the earth has ever seen.

It is not our object here to discuss the Dinosaurs themselves, but several prominent facts must be noted: they spread over the earth, and essayed both air and sea; on a very moderate estimate they lasted from 5 to 10 millions of years; they showed a diversity of structure surpassing that of mammals. Some were herbivores that ground up coarse vegetation, and others, without teeth, sucked up juicy marsh plants. Some were small carnivores preying on other little creatures, including eventually the minute and timid mammals that were beginning to show face, while others of gigantic size were "the most terrible devourers of flesh the world has ever seen". As to size, the smallest was the size of a cat; the largest had a length of 80 feet, and a probable weight of 40 tons. They entirely disappeared at the close of the Cretaceous; but they did not wholly die, for they had meanwhile given origin to both birds and mammals. But while these are scions of two Dinosaur stocks, they are not to be regarded as direct descendants; and the large fact remains that none of the highly-successful groups of Dinosaurs survived the end of the Mesozoic. All were "lost races".

In regard to the vegetation in the days of the Dinosaurs, i.e. in the Mesozoic (Triassic, Jurassic, Cretaceous) Era, it was very different from that of to-day. Some of the Palæozoic plants, such as horsetails and club-mosses and old-fashioned ferns, still persisted, occasionally with vigour, but the characteristic feature was the abundance of Gymnosperms, that is to say, seed-plants with naked seeds. The dominant groups were Conifers, Cycads, and Maiden-hair Trees. Most characteristic were the Cycads, and "it is impressive to find that a class now insignificant in extent then dominated the world". One great authority on the evolution of plants has calculated that out of all the Mesozoic land-plants in the days of the Dinosaurs, one in every three was a Cycad; and another authority computes that two out of every five land plants of this era were Cycads. But Cycads are unfamiliar plants to-day.

It must be noticed, however, that in the Upper Cretaceous, when the Dinosaurs were beginning to show hints of racial senility, there was an apparently sudden emergence of the Flowering Plants or Angiosperms that are familiar to us to-day. The Cycads dwindled and the Flowering Plants took their place; the Dinosaurs disappeared and the warm-blooded Birds and Mammals began to make headway.

LIFE OF THE CARBONIFEROUS PERIOD.—It would be a great scientific delight if we could shut our eyes and see with the inner eye the appearance of the earth and its inhabitants in one geological period after another. What a magnificent film it would make, with the changing stage æon after æon through millions of years, and on the stage the likewise changing plants and animals vividly portrayed. How dramatic it would be to see the intrusion of Ice Ages not only in the Pleistocene, but over and again as far back as the Cambrian, and worst of all in the Permo-Carboniferous. How impressive to follow the retreat of the fauna before the great glaciers, and to witness the inexorable elimination by the way. How thrilling it would be to study on the film the other Ages of Horror, the desolating times of drought and aridity, when animals trekked before the encroaching desert.

On such a film the Carboniferous Period would furnish many picturesque scenes, such as vast stretches of low-lying luxuriant forests of quickly growing spore-bearing trees, and in these forests many insects, spiders, snails, and the like, besides Amphibians great and small. Sharks seem to have ruled the seas.

In the later part of the Carboniferous Period the coal-measures were laid down in humid low-ground forests; and the climate throughout most of the period was mild and damp. There were no dry seasons, or cold winters, and the conditions favoured luxuriant vegetation and abundance of insect life. It is said that the fossil trees of the period show nothing corresponding to the annual rings of coniferous or phanerogamic trees, for these are due to the difference between the growth of the wood in the earlier and the later summer months and its annual arrest in the resting season. There seems to have been much stagnant water, which teemed with the aquatic larvæ of insects and with amphibians large and small. Often in all probability the conditions were mild and easygoing; yet did not the coal then formed make our steam age possible?

The coal-making forests consisted largely of graceful trees distantly related to our Horsetails, but sometimes reaching a height of a hundred feet. Along with these were giant club-mosses and tree-ferns, and some of our coal shows that there must often have been great showers of spores like the "sulphur showers" of pollen which are often swept by the wind from the pine forests of modern times. But the Carboniferous flora included much more than Cryptogams; there was a great luxuriance of seed-bearing plants of fern-like habit (the "Seed-Ferns", Pteridosperms or Cycadofilices), and there were lofty large-leaved trees, called Cordaiteæ, intermediate between the primitive maiden-hair trees (Gingko) and the Conifers we are familiar with. Perhaps the "Seed-Ferns" gave rise to the Cycads, which are sparsely represented in warm countries to-day, but once formed great forests; and perhaps the Cordaiteæ gave rise to our

Conifers, such as the pines. In any case, we must think of the larger Carboniferous land-plants as including the non-seeding ferns and tree-ferns, club-mosses and "horsetails", but also the seed-bearing Pteridosperms and Cordaiteæ, two classes now lost in their evolved descendants. As far as Man is concerned, the richness of the Carboniferous vegetation was of an importance that cannot be exaggerated, not only because we are still using the stored energy of coal when we can—and not always according to our lights—but because it was in the Carboniferous Period that seeds were evolved. For where would man be without seeds?

Much is known in regard to the Carboniferous insects, many of which were generalised types, each pointing on, not to one, but to several of our modern orders. Thus the Protoblattoidea are believed to be ancestral not only to the cockroaches, which they suggest, but to termites, book-lice, bird-lice, and beetles. The mild climate must have suited insects well, for they attained large size; thus some Carboniferous dragonflies had a spread of wing of 29 inches. The body of a huge walking-stick insect (Titanophasma) from the Coal Measures of France is upwards of a foot long. Many of the Carboniferous insects were amphibious; some were aquatic in their young stages only, just like our dragonflies and Mayflies; but others were terrestrial from first to last. In those days there were no flowers to visit, and the mouth-parts of most of the Carboniferous fossil-insects that have been deciphered suggest carnivorous habits. Another feature is the apparent absence of the quiescent stages which we know as pupæ or cocoons in all the higher insects of modern times. This meant in part that the mild and doubtless even warm Carboniferous winters could be survived by insects in the adult state. The colonisation of the dry land had also been effected thus early by centipedes and millipedes, and by spiders and scorpions, while on a very different line there were a few land-snails, which carried on the experiment successfully begun in the time of the Old Red Sandstone.

The highest animals in the Carboniferous seas were the fishes, and there seem to have been a great many sharks, some approaching closely to the Port Jackson shark type. There were also representatives of a very progressive order, that of the Fringed-fin fishes (Crossopterygians), which have only two living relatives to-day (Polypterus and Calamoichthys), yet may have been ancestral to both lung-fishes and amphibians. But the *dominant* fishes in the Carboniferous seas were primitive, no longer represented, yet forerunners of the sturgeons, spoon-bills and gar-pikes, and eventually of the ordinary Bony Fishes of to-day. The big fact is that besides the gristly sharks, the progressive Fringed-fins, and the mud-fishes or lung-fishes, there were in the Carboniferous waters the early representatives of the Bony Fish type (Teleosteans), which later attained supremacy.

In a sandstone slab dating from the end of the Old Red Sandstone or Devonian Period there is a footprint with three distinct toe-marks and a hint of a fourth—the earliest record of a terrestrial backboned animal. It is one of the treasures of the Museum at Yale, and the creature that made it was called *Thinopus antiquus*. But while this footprint is eloquent, it does not carry us very far; and it is satisfactory to find in Carboniferous strata many fossil Amphibians. Some were small and newt-like, others huge and heavily armoured. Some wallowed and others crawled sluggishly, and others, having lost their limbs, could only swim. It was a Golden Age of Amphibians; and our imagination cannot but be thrilled when we look at these Carboniferous skulls and skeletons, the remains of animals that were the first to have fingers and toes, true lungs, a three-chambered heart, a movable tongue, a drum to the ear, and a voice breaking the silence of Nature. There are distinct fossilised traces of a gill apparatus in some of them; and the eggs were doubtless laid in the water, as is the case with most Amphibians to-day. But perhaps the biggest fact is that these ancient Amphibians, following in the footsteps of Thinopus, were the first vertebrate animals to invade the dry land with success. They made the higher animals possible, for they gave origin, probably in the Carboniferous Period, to Reptiles, whence in the course of time there emerged both Birds and Mammals.

PERMIAN.—The easygoing life of the Carboniferous was certainly not uninterrupted, yet on the whole it was a period of luxuriance as compared with the Permian, during which the life struggle became sterner. In some areas there was uplift and aridity, making it more difficult for the progressive Amphibians to go back to the waters to spawn; and this must have proved a spur to the evolution of terrestrial Reptiles and their fœtal membranes. In other areas, especially in the Southern Hemisphere, there was widespread glaciation, even more severe than in the Pleistocene Ice Ages, and this involved an elimination of many of the older spore-bearing plants, e.g. among the ferns and tree-ferns and horsetails. Hardier seed-bearing types began to flourish—such as Conifers, Cycads, and Gingkos. The Lower Permian plants are largely spore-bearers, like those of the Carboniferous Period; the Upper Permian plants show an increasing number of seed-plants. In technical language, the change from the "Palæophyticum" to the "Mesophyticum" took place in the middle of the Permian Formation. Zoologically we think of the Permian Period as the time of the rise of reptiles and the beginning of a physiological movement towards warm-bloodedness. Associated with the Permian Ice Ages, there was probably an interpolation of pupa or chrysalid phases in the life-history of many insect types.

TRIASSIC.—There seems to have been a prevalence of desert

conditions in Triassic times, and with this may be associated the waning away of many of the older spore-bearing plants and a new impulse to the seed-bearers. The difficulty of linking the Mesozoic vegetation to the Palæozoic has led some botanists, notably Church, to the theory that there was a recurrent colonisation of the land from the primeval marine plants—an inexhaustible Algoid stock.

Zoologically we think of the Triassic Period as one in which the dominant reptiles made many tentatives of habit and showed many divergences in detailed structure. Probably associated with the aridity was the acquisition of a bipedal mode of progression by some of the Dinosaurs. It is interesting to notice that the large (up to 5 feet) Collared Lizard (Chlamydosaurus) of Australia is at home in arid conditions, and is strikingly bipedal; and there are other instances of the correlation. The first known remains of mammals are Triassic; they seem to have been pigmies as compared with the reptiles, but there was a promise of victory in their brains.

FISH-LIZARDS OR ICHTHYOSAURS.—Ichthyosaurs were once common in the ancient seas; they ranged from the Triassic, through the Jurassic, to the Cretaceous, when they disappeared. We do not know from what simpler stock they may have been evolved; and we do not know that they had any descendants. Appearing in large numbers from an unknown ancestry, they had their Golden Age for millions of years. For some unknown reasons they then began to decline, and there is no trace of any after the Chalk Period. Their remains show no particular resemblance to those of any other order of reptiles, extinct or extant; they form a somewhat homogeneous order of reptiles, quite by themselves and in many ways unique.

We know that Ichthyosaurs were marine, and that they were carnivorous; that they varied in size from a yard in length to 30 or 40 feet; and that, apart from the somewhat primitive Mixosaurus and the somewhat decadent Ophthalmosaurus, they were all very like one another, being similarly adapted to swift swimming in the sea and to catching cuttlefishes and true fishes. This meant some expertness in swimming, and for this the shark-shaped or dolphin-like body was well suited. It says something for palæontology that a diet of cuttlefishes can be safely inferred from the fossils, for the parrot-beak-like jaws, characteristic of Cephalopods, are easily recognisable inside the petrified body. It may be that the appetite of the Ichthyosaurs accounts for the disappearance of some of the ancient types of cuttlefishes long since extinct.

Picture a lithe body, almost neckless, more porpoise-like than shark-like, with a long-snouted skull and two pairs of somewhat paddle-shaped limbs. Perhaps "trowel-shaped" would be a more accurate term, for they tapered to a point. On the back there is a jagged fatty fin, or a succession of several. There may be some

indication of horny scales about the front and base of the fore-paddles, but otherwise the fish-lizards seem to have been smooth-skinned, just as the mammalian cetaceans at a much later date became.

An interesting point is that the tail had a large bilobed vertical fin like that of a shark, not a pair of horizontal flukes as in whales and dolphins; but whereas the end of the vertebral column of a shark is prolonged into the upper half of the unsymmetrical tail, it is prolonged into the lower half of the also unsymmetrical tail of the Ichthyosaur. When a shark strikes with its tail—upper half the larger—the movement tends to depress the head, unless, of course, the shark has turned upside down, as it often does, at the surface. But as the stronger half of the fish-lizard's tail is the lower one, into which the end of the vertebral column is abruptly bent, the stroke must have tended to bring the head up—and this, as one of our old professors first pointed out, would tend to lift the head and its nostrils upwards at the surface, an obvious adaptation for a lung-breathing reptile.

The skull is drawn out into a long snout, which is mostly made of the bones that become exaggerated to frame the beak of a bird, namely, the premaxillæ. As in all birds, except the kiwi (Apteryx), the nostrils are far back. The orbits for the eyes are remarkably large, and we see that the front of the eyeball was protected by a ring of bone—the sclerotic ring. But this occurred in many of the extinct reptiles, and formed part of the legacy that certain Dinosaurs handed on to birds, these surprising scions of an adventurous, though markedly pedestrian stock.

On the top of the Ichthyosaur's skull there is a well-marked hole —the parietal foramen—which lodged the pineal body, that strange, upward-looking median eye, represented in some degree in all Vertebrates from lamprey to man, but showing only in a few animals to-day, such as the New Zealand "lizard" or Sphenodon, distinct traces of optic structure. It is the organ about which we are always told that Descartes regarded it as the seat of the soul. If so, it was very generous of him, for it means including as besouled the lamprey and the tadpole, the slow-worm and the Ichthyosaur, and thousands of more ordinary Vertebrates.

In most Ichthyosaurs the conical teeth, suggesting those of some of the toothed whales, are placed in a continuous groove. They were evidently suited for seizing and gripping slippery prey rather than for chewing. From the shape of the fossilised alimentary debris (coprolites) it seems clear that the Ichthyosaurs had a "spiral valve" like that of sharks, i.e. a spiral staircase inside the (otherwise shortened) intestine, which serves to increase the surface for absorbing the digested food. Thus of a type of animal that left the stage millions of years ago we can say that it fed largely on cuttle-

fishes, that it bolted its food, that it depended chiefly on fishes and cuttlefishes, and found the chitinous beaks of the latter more difficult to digest than the bones of the former. Not less remarkable is the ocular demonstration of the fact that Ichthyosaurs were viviparous, bringing forth their young ones as miniatures of themselves. This is very well shown by some specimens in the Stuttgart Museum, where the unborn fossil offspring are conspicuous inside the fossil mother. Thus the dead bones live!

The York Museum has amongst others a fine specimen of *Ichthyosaurus crassimanus*, which must have been about 30 feet long. It shows very clearly that the ordinary long bones of the limbs are in fish-lizards very short, the main part of the paddle being the hand or the foot. We counted the finger-joints on the paddle, and one had nine, instead of the usual three; and in some cases the number rises to twenty! In all probability the chief swimming organ was the posterior body, including the tail, the paddles being used chiefly for steering and balancing. It was not advantageous that the paddles should be long, but they retained great developmental vigour, which found staccato expression in a multiplication of finger-joints. Sometimes, moreover, the third digit has divided longitudinally in the course of development, so that the number rises to six.

Lung-breathing animals could not begin in the sea, so we must look for the ancestors of fish-lizards among extinct terrestrial reptiles. In the yard-long Mixosaurus the limb is not so paddlelike as in typical forms; the teeth are not in a continuous groove; and the vertebral column is not bent down into the tail as much as usual. Even in regard to the peculiarly isolated Ichthyosaurs, evolution proves itself.

JURASSIC.—During part of the Jurassic Period there seems to have been a milder and more humid climate, with swampy stretches along the shores of shallow seas, and an abundant vegetation, partly consisting of seed-plants. It was probably in these rank meadows that some of the giant reptiles found sustenance, enjoying a somewhat hippopotamus-like semi-aquatic life.

In inland sun-baked stretches, rising into cliffs, there was a welter of more active reptiles, illustrating evolutionary radiation in many directions, and including some "flying dragons", such as Rhamphorhynchus, with a skin-wing outstretched on an enormously elongated fourth finger. Not related to them and destined to be more successful were the pioneer birds, but the Jurassic Archæopteryx is already too specialised to have been the first representative of the class. There is no real difficulty in the fact that the first *known* fossil mammal is Triassic, while the first *known* fossil bird is Jurassic. Birds and mammals are on quite different evolution paths, diverging from different reptilian origins.

CRETACEOUS.—The beginning of the Mesozoic (or Geological

Middle Ages) is often dated at about 60 million years ago, and the beginning of its third and last period, the Cretaceous, at about 30 million years ago. The Cretaceous Period gets its name from the abundance of chalk deposits, but there are many other kinds of rocks. It lasted for some 15 million years, and ended in great crust-movements, sometimes called the "Laramide Revolution".

In the Lower Cretaceous there was a continuation of the characteristic Mesozoic plants, such as the Cycads and their relatives, but the flowering plants were beginning to come to their own, and one of the great events of the Cretaceous Period was the growing dominance of Monocotyls (like reeds and palms) and Dicotyls (like magnolias and laurels). Expressing it technically, we may say that Angiosperms began to gain on Gymnosperms. The flora of the Lower Cretaceous is ancient, that of the Upper Cretaceous is modern.

In Cretaceous times the evolution of reptiles continued apace, and numerous specialised types arose. But even in the Lower Cretaceous there were indications of the waning of the small-brained giants. There were new Flying Dragons or Pterodactyls, some of which probably caught fishes from the surface of the sea. One of these strange types, Marsh's Pteranodon, had a wing span of over 24 feet and an extraordinary skull about 6 feet long, but it probably did little in the way of active flight. From the restricted dimensions of the pelvic girdle it has been inferred that the newly hatched young were very small. Not related to the Pterodactyls were the true birds, which included in Cretaceous times some modern types. Of great interest was the increase of small and primitive mammals which were gradually to supplant their reptilian predecessors. The overthrow of the reptilian dynasty was associated with crustal changes, culminating in the Laramide Revolution, and one of the factors was probably the obliteration of the low-lying coastal haunts. Towards the end of the Cretaceous there seems also to have been a widespread lowering of temperature. In any case it was a dramatic time when small furry quick-witted mammals began to supplant the large, brawny, well-armoured, but slow-going reptiles.

TERTIARY OR CENOZOIC.—For our purpose in this book it is unnecessary to follow the sub-divisions of the Tertiary or Cenozoic Era, which may well be called the Age of Mammals, when brains began to be of much greater survival value than brawn. But it is interesting to notice that the first period, the Eocene, was marked by numerous archaic or generalised mammals, which were replaced in the Oligocene and Miocene by the modern orders, such as Carnivores, Ungulates, Bats, and Monkeys. A general land-elevation led to the widespread dominance of certain types of vegetation, such as grass-lands, which do not require a high degree of moisture. The clothing of large areas of the earth with a garment of grass must

have had a great influence on the evolution of grazing mammals, and it must also have meant a great reduction of superficial erosion.

The fourth of the Tertiary periods, the Pliocene, seems to have been a time of restless strenuous life, with many changes in the surface features of the earth and with many trekkings and explorations, as well as eliminations. It was probably in the Pliocene, that tentative men began to appear, and there was probably much sifting in their evolution.

PLEISTOCENE OR QUATERNARY.—In the Cenozoic Era man was still on trial, and not yet at the level of Homo. The elevation of the continental masses went on and a combination of factors led to the setting in of the prolonged Glacial Periods or Ice Ages, interrupted

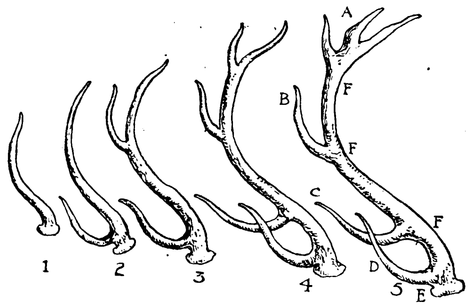


FIG. 144.

Antlers of Stag, from second year onwards (1–5). The points A–D on the six-year-old stag are called tynes, which are increased in number with each fresh growth. The antlers fall off at the end of the season, and the growth next year begins again at the beginning. The figure would also serve in a general way to indicate the increase of complexity in the course of evolution through successive geological periods. In other words, the figure may serve for phylogeny as well as for ontogeny.

by three milder Interglacial times. These times of smothering ice-sheets and fatal cold involved no doubt terrible elimination, but they also served in some cases to stimulate endeavour at many levels. It was towards their close that Homo definitely emerged and was well represented by Neanderthal Man.

GREAT STEPS IN STRUCTURAL ADVANCE

In thinking of Organic Evolution, one naturally concentrates attention on the emergence of the great classes: When and whence was the origin of Birds or Insects, Seed-Plants or Ferns, and so forth? But prior to these particular problems, there are larger ones —the origin of the multicellular body, of sex, of blood, of brains, of limbs, of viviparity, and so on. Even though one cannot as yet advance far in explaining these and other great achievements of

life, it is well that the problems should be stated and the steps envisaged.

ORIGIN OF ORGANISMS.—It is probable that the earth as a planet is some 2,000,000,000 years old, and it is probable that far more than half of that unthinkable time was spent before the crust became cool enough and moist enough to be a home for living creatures. Perhaps these emerged 300,000,000 years ago, but some calculations, which are not guesses, give three times more. Since protoplasmic life can only continue below a certain limit of temperature and demands, as a *sine qua non,* water in a liquid form, its emergence must not be pushed back beyond the time when the earth fulfilled these conditions. Our question is how did organisms begin to be upon the earth. Some thinkers regard it as almost impious to go beyond the theological or religious answer: that "Protoplasm is a handful of dust that God enchants". In other words, living creatures arose in a manner beyond Science—as an expression of the Creative Will. But however true this may be transcendentally, it is not a scientific answer. It involves a premature abandonment of the scientific quest, though it will not and cannot be affected by any scientific answer that may be found.

Another position is that of the scientifically agnostic: *Ignoramus*; and as a matter of fact no one *knows* how living creatures began to be upon the earth. The problem cannot be an easy one; there is not in biological experience any known exception to the conclusion—*omne vivum e vivo*; we are not even sure that life ever began; perhaps we are not putting the question in the right way. But admirable as this scientific reserve may be, it is a little too superior. In any case, while it may be too soon to answer a question, it is never too soon to ask it, if we can ask it well. And that requires some trying.

Thus after bowing to the theological and the agnostic positions, we find ourselves before two answers. The first, associated with the names of Kelvin and Helmholtz, Richter and Arrhenius, and therefore not to be brushed aside, is that minute germs of life may have come to the earth from elsewhere, ensconced in a meteorite or wafted with cosmic dust. It has been shown by Becquerel and others that simple and quiescent forms of life can survive prolonged exposure to extreme conditions of temperature, drought, and scarcity of oxygen. Life in its simplest forms is very hard to kill, and it may have come to the earth from elsewhere. But this would leave quite untouched the problem of its origin "elsewhere".

The other answer is the evolutionist one, that the living may have arisen from the not-living by some process of natural synthesis, comparable to the laboratory achievements of the chemist who builds up compounds like grape-sugar, oxalic acid, indigo, caffein, adrenalin, thyroxin, and so forth. The proteins, which are the most

important constituents of living matter or protoplasm, are linkages of amino-acids, and these amino-acids can be built up synthetically. The probability is that the artificial synthesis of proteins will be achieved.

The difficulty is to picture how this synthesis might be effected in natural conditions upon the earth,—a difficulty that is increased by the fact that there does not seem to be any even approximately analogous process going on at present. It is possible, however, that it may have occurred in different conditions when the earth was younger. It is also possible that natural synthesis still continues apart from life, though it has not been detected.

Some physiologists have looked to cyanogen (CN) as possibly affording a starting-point in the hypothetical synthetic process leading on to protoplasm. Cyanogen and its compounds may be formed in incandescent heat, and might arise while the earth was still hot. The cyanogen compounds are unstable and might readily form linkages with other compounds, especially when water began to be precipitated on the cooling crust of the earth.

More promising, perhaps, is the hint afforded by the experiments of Baly, which have shown the possibility of using light-rays so as to produce from water and carbon dioxide the sugar that is built up in the green leaf. By adding a nitrogen compound, a further synthesis was effected. As nitrate of ammonia or something similar might be carried by a thunder-shower into a sunlit pool with carbon dioxide in the water, it is possible that nitrogenous carbon compounds might be synthesised in natural conditions.

"It may be objected that our problem is not the origin of living matter or protoplasm merely, such as we might squeeze out of a sponge or some similar simple animal, but the origin of a living creature, an organism, a viable unity. What can one answer save that the tendency to integration, hypothetically manifested in the synthesis of protoplasm, may have continued into the integration which led to the first organisms? These were probably very short-lived, perhaps only creatures of a day, dying, as they multiplied, in the cold of their first night. But their radical distinction from the non-living was that they were going concerns, able to balance their matter-and-energy accounts for at least a short time. It is probable that it was during this integration of the first organisms that mind emerged, in flashes at least. One may perhaps ask whether the difficulty of the problem of the origin of living creatures may not be due in great part to the *psycho*-biological nature of the momentous integration." (Thomson, *Concerning Evolution*, 1925, p. 47.)

THE FIRST ORGANISMS.—This inquiry must be essentially a speculative one, yet it may not be unprofitable to try to picture the first organisms. Not much help can be got from the study of

ordinary Protozoa (unicellular animals) and ordinary Protophytes (unicellular plants), for most of these (like Amœbæ, Slipper Animalcules, Pleurococcus from the tree-stem, and yeast-plants) are already, in spite of their relative simplicity, too highly specialised. They are not at all within hailing distance of the first organisms; a Protozoon like Paramœcium is extraordinarily intricate and to call it "a simple cell" is almost fallacious. It is a very complex organism, within the non-multicellular phase of being. If we look for light as to primitive organisms from creatures of to-day, we must look to very much simpler organisms than Slipper Animalcules or Amœbæ. It is possible that the often minute Chlamydozoa, which are near the border-line of microscopic visibility, may give us hints—when we know more about them—in regard to the original organisms.

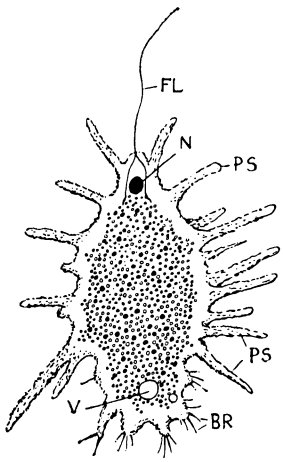


FIG. 145.

An Infusorian, Mastigamœba, which is at once amœboid with pseudopodia (PS) and flagellate with a lash (FL). N, the nucleus; V, a vacuole; BR, basal processes.

If there is any general view as to the first organisms, it is that they were perhaps like much simplified Amœbæ, little unities of colloidal proteins, and these beginning to come together into larger masses; incipiently *correlated*, that is; and (somehow) able to utilise the radiant energy of sunshine so as to build up more proteins, or antecedent stages of proteins, from environing material; able to keep agoing, to balance accounts; *viable*, that is. Many a zoologist still, surely too simply, pictures a first organism as like a simplified Amœba—an Amœba reduced to essentials. So, too, the botanist pictures a first organism as like a simplified Pleurococcus, or Yeast-plant, or Bacterium. Perhaps the simplest current view is that of a colloidal protein-integrate, without structural definiteness, much less complexity; yet a protoplasmic firm, a unity able to divide, a creature able to go on, to pay its way, to balance accounts, and of

course to continue itself, in whatever piecemeal fashion. The focus of this picture is on the integrating of proteins which "find themselves", and gradually establish function and form as a still very simple organism suggests.

The late Prof. Minchin, in his presidential address to the Zoological Section of the British Association meeting in Manchester in 1915, elaborated a theory of the early stages in the evolution of organisms which stands in marked contrast to that usually held. The usual view starts with units of protoplasm and supposes a secondary differentiation of the characteristic nuclear material, chromatin. Prof. Minchin thought it more reasonable to start with little corpuscles of chromatin, which subsequently gave rise to forms with a surrounding matrix of protoplasm. The nucleus or kernel of a cell is rich in this very complex protein material, chromatin, a protein with a considerable percentage of phosphorus, which plays a leading part in vital processes. It occurs in many cases in the form of definite bodies or chromosomes, constant in number and often specific in shape. When the cell divides, the chromatin is divided and usually with extraordinary precision, between the two daughter-cells. Thus Prof. Minchin was inclined to regard the chromatin as more fundamental than any other constituent of a living unit. Its presence in the nucleus of the cell is invariable, and grains of it are often present in the extra-nuclear cell-substance or cytoplasm as well.

"I regard the chromatic elements", Minchin said, "as being those constituents which are of primary importance in the life and evolution of living organisms mainly for the following reasons: the experimental evidence of the preponderating physiological rôle played by the nucleus in the life of the cell; the extraordinary individualisation of the chromatin-particles seen universally in living organisms, and manifested to a degree which raises the chromatinic units to the rank of living individuals exhibiting specific behaviour, rather than that of mere substances responsible for certain chemico-physical reactions in the life of the organism; and last, but by no means least, the permanence and, if I may use the term, the immortality of the chromatinic particles in the life-cycle of organisms generally." (*Report Brit. Assoc.*, 1915, p. 451.)

The hypothetical primitive organisms which Prof. Minchin started with, calling them Biococci, were very minute specks or globules of chromatin, or of some allied substance. He supposed that they were able to build up protein-molecules from simple inorganic compounds, that they reacted upon their environmental medium by means of ferments secreted by their own substance, that they multiplied by dividing into a dumb-bell shape, and that different kinds had their distinct specificity or individuality.

From these "Biococci" as starting-point, a bacterial type of

organism—a step along the vegetative line—might readily arise by a firm membrane being formed around the globule of chromatin. A cytoplasmic matrix might be added, and the enclosed chromatin bodies might increase in number and assume various shapes and arrangements.

A step in a different direction—towards a predatory or animal mode of life—may have been made by the formation—round a biococcus, or around several biococci—of an enveloping matrix of changeful protoplasm (or periplasm) with streaming movements, amœboid outflowings, and included vacuoles. "Thus arose in the beginning the brand of Cain, the prototype of the animal—that is to say, a class of organism which was no longer able to build up its substance from inorganic materials in the former peaceful manner, but which nourished itself by capturing, devouring, and digesting other living organisms. The streaming movements of the periplasm enabled it to flow round and engulf other creatures; the vacuole-formation in the periplasm enabled it to digest and absorb the substance of its prey by the help of ferments secreted by the biococci. By means of these ferments the ingested organisms were killed and utilised as food, their substance being first broken down into simpler chemical constituents and then built up again into the protein-substances composing the body of the captor."

A further step towards a true cell consisted in the multiplication of the enclosed biococci so as to form numerous chromatin grains scattered through the protoplasm. Some living Protozoa show this "cytodal" phase as a transient chapter in their life-history.

The next stage in evolution was the organisation of the chromatin-grains (biococci) into a definite cell-nucleus, a complex microcosm with a framework (of linin) supporting variously disposed chromatin constituents. While most of the chromatin grains became aggregated to form a nucleus, others remained as scattered "chromidia" in the protoplasm. This was the first true cell, and the starting-point of many lines of further evolution.

Prof. Minchin's theory is vivid and some of the steps assumed have their counterparts in what goes on to-day, e.g. the condensation of scattered chromatin grains to form a secondary nucleus. It seems difficult, however, to think of the primitive organisms as specks of chromatin, seeing that chromatin is an exceedingly complex protein substance. It thus seems more in line with evolutionary speculation to think of a blend of simpler proteins forming a unit of protoplasm. Yet it must be remembered that there is no proof that the general cytoplasm of a cell, or of a Protozoon, can form digestive ferments without the co-operation of chromatin.

Another theory that is certainly interesting has been propounded by Mereschkowsky. It assumes a double origin for organisms, which are supposed to have arisen from a combination of two quite different

kinds of protoplasm, originating at different times. The first kind, "mycoplasm", was formed when the waters covering the earth were still hot, if not near boiling-point; it is of the nature of chromatin, and is well represented in Bacteria for instance. The second kind, "amœboplasm", was formed later, and fed upon Biococci, consisting of particles of mycoplasm. But some of these Biococci, ingested by the primitive amœboid units, defied digestion, and became internal partners of their captors. Eventually they formed nuclei. The locomotor powers of the primitive amœboid units were abetted by the ferment-making powers of the engulfed Biococci.

THE DIVERGENCE OF PLANTS AND ANIMALS.—Linnæus made a wise use of the term "Organisata" to include both plants and animals, for they stand together as organisms, in contrast to things in general. Claude Bernard in his famous—and even classic—essay, *Phénomènes de la Vie communs aux Animaux et aux Végétaux* (1878), showed how much there is in common in the vital processes of the two "kingdoms". In their cellular structure, and in the individual development from a fertilised egg-cell, there is further illustration of the fundamental unity of plants and animals. There is a vegetative side to the most vigorous animal; there is something of the beast imprisoned in many a plant. Yet, after all, plants and animals are very different. They represent different ways of attacking and solving the problem of surviving and mastering; they exhibit different physiological régimes, different policies. And one of the early great steps in evolution must have been the divergence of plants and animals.

The contrasts between typical plant and typical animal are many and obvious, but there are many simple organisms which are not emphatically on either line of evolution. It is difficult to be sure whether the "Flowers-of-Tan" (*Fuligo varians*), a pest that creeps on the bark of the tanyard, should be called a plant or an animal. It belongs to the class of Myxomycetes, which botanists claim as "slime-fungi", and zoologists as primitive Rhizopods, which may, however, be neither, yet something of both. Such organisms suggest that though the genealogical tree of Organisata be somewhat Y-like, there were undecided organisms for a long time before the great dichotomy occurred.

What is the fundamental contrast between plants and animals? Plants are organisms that are able to obtain nutritive materials at a low chemical level, able to synthetise relatively simple inorganic substances—notably carbon dioxide and water. Animals are organisms that feed at a high level, on the carbon compounds manufactured by other creatures. It is probable that the dichotomy began long before there was chlorophyll, which is now so important in the photo-synthesis characteristic of green plants. The fundamental

contrast is between low-feeders and high-feeders, and though it was accentuated by the evolution of chlorophyll, it was in all probability independent of this pigment. Thus there are a number of Bacteria which are able to fix the free nitrogen of the air—a distinctively plant-like performance, yet independent of chlorophyll. The capacity for chemical synthesis implies the making of compounds readily broken up again; but plants do not themselves use nearly all they make. There are movements, as of shoots and roots, of leaves and tendrils, stamens and stigmas, and carried further in cases like Venus's Flytrap and Sundew tentacle; but, on the whole, plants do not expend much of their energy in these active ways. Animals are characteristically users of the explosive carbon compounds made by other creatures. Thus, while we may say that "feeding-low" and "feeding-high" is the fundamental difference between plants and animals, the central difference is that typical plants live below their income, typical animals live close up to theirs. The ratio $\frac{\text{Anabolism}}{\text{Katabolism}}\left(\frac{A}{K}\right)$ in the plant is relatively greater than the corresponding ratio $\left(\frac{a}{k}\right)$ in the animal. In the typical plant, possessed of chlorophyll, the numerator of this fraction is always much greater than the denominator; in the animal the denominator is always creeping close up to the numerator, the expenditure to the income. Many detailed differences are associated with this central difference: thus the plant-cell becomes characteristically imprisoned in a cell-wall of cellulose, while the animal gains energy by burning down its carbohydrates completely to carbon dioxide and water; and there is not in plants any function closely corresponding to the nitrogenous excretion of animals. Waste products are indeed got rid of in falling leaves and the like, but they also tend to accumulate in the plant body, e.g. in the form of crystals; and may even tend to lower the fire of life. Sometimes, however, they re-enter the nutritive cycle before they become poisonous.

To the question whether plants or animals appeared first, it may be answered that the early organisms were neither the one nor the other, though surely nearer the plant-like mode of life than the animal-like mode of life, inasmuch as they would need somehow to synthetise proteins from relatively simpler substances not yet organic. When the predatory mode of life was established, organisms devouring other organisms, then animal life definitely began. When the synthetic processes became dominant in the metabolism, then plant life definitely began. Chlorophyll would soon become characteristic of the majority, though it is possible that it may have appeared before there were definite "plants". In any case, it must always be remembered that it is on the photosynthesis achieved by chlorophyll-

possessing plants that the existence and evolution of the whole animal kingdom has since depended.

Prof. Minchin's suggestion as to the origin of green plants was that they diverged from a stock of Flagellate Infusorians which formed or became possessed of chlorophyll corpuscles or chromatophores. There are some of the Flagellate Infusorians that have a mouth and digestive vacuoles and an animal way of eating, and yet have chlorophyll corpuscles so that they can also live like plants. In technical language they are said to combine the holozoic and a holophytic mode of nutrition. An abandonment of predatory life, a reliance on the photosynthesis of organic substances, a consequent accumulation of reserves, and a nemesis of sluggishness might eventuate in a definite plant at a unicellular level. "It would be interesting", Minchin said, "to know exactly what these chromatophores, at their first appearance, represent; whether they are true cell-organs, or whether, as some authorities have suggested, they originated as symbiotic intruding organisms, primitively independent." It must be understood that a few Protozoa, such as *Vorticella viridis*, have chlorophyll of their own, while others, like *Stentor polymorphus*, have green symbiotic Algæ. The establishment of a partnership with symbiotic green Algæ, e.g. Zoochlorella, occurred repeatedly, e.g. in many unrelated Protozoa, in *Hydra viridis*, in many Anemones and Alcyonarians, and in the simple planarian worm, Convoluta (see section on Symbiosis).

It is possible, however, that the green pigmentation of some Flagellate Protozoa is not to be regarded as indicating a probable origin for green plants. Minchin's view would postpone the evolution of green plants till there were animals as definite as Flagellata, whereas one inclines to think of the dichotomy as occurring at a much lower level. As to Bacteria, Minchin regarded them as very primitive, non-cellular, vegetative organisms, directly derived from the primeval Biococci, and not, as some maintain, either degenerate or highly-specialised cells.

On Mereschkowsky's daring hypothesis already referred to, the first type of protoplasm, *mycoplasm,* was represented by very minute, very hardy, Biococci with the power of building up proteins and carbohydrates from inorganic materials. From these arose Bacteria, which were for a long time the only living creatures besides the Biococci. Afterwards there evolved the Blue-Green Algæ (Cyanophyceæ) and the Fungi. These three groups—Bacteria, Cyanophyceæ, and Fungi—formed a Kingdom by themselves, *a Kingdom without symbiosis*, the Mycoidea.

When Mereschkowsky's second kind of protoplasm, *amœboplasm,* appeared on the stage in a cooler sea, it was represented by minute amœboid Monera. These entered into partnership with Biococci, and the Animal Kingdom began. In a typical animal cell the

chromatin corresponds to the Biococci (mycoplasm), and the cytoplasm to Monera (amœboplasm). So the somewhat luxuriant speculation continues!

But from simple flagellate or amœboid organisms there was evolved the Vegetable Kingdom as well, apart from the Bacteria, Cyanophyceæ, and Fungi. For Mereschkowsky supposed that certain Cyanophyceæ entered into partnership with the true cells already accounted for, and were eventually represented by the chromatophores or chlorophyll-corpuscles of green plant cells. Thus green plants would arise by a double symbiosis. Further speculation is aroused by the comparatively recent discovery of filter-passing organisms.

BACTERIAL FORM AND LIFE.—Nothing is more characteristic of our habits of thinking and teaching in biology than our customary start with the "Proteus animalcule" of old naturalists, the common Amœba, as one of the simplest and most elemental forms of life within easy observation; so this affords not only a convenient start for teaching, but interest ever yielding fresh ideas and results. These we carry onwards from this simple life-form and its life-cycle to the multitudinous variety of protozoan and protophytic forms. From these, we consider our best way of approach to the "higher" —because multicellular and integrated—Metazoa, and find the sponges easiest to begin with, albeit with their own complexities beyond the unknown simpler predecessors we may try to imagine. So, too, the botanical teacher starts with his simplest unicellular Algæ, and goes onwards. Since among the simplest Protozoa and Protophytes there are forms which can hardly be considered as yet distinctly animal or vegetal in character, there is something to be said for Haeckel's union of such forms into a group below Protozoa and Protophytes, as Protista: but the present point is, that all these ranges of organic life are unified within the great generalisation of the cell-theory; since our biological observations and interpretations have essentially arisen within its limits.

The comparatively recent yet now extensive field of Bacteriology, however, lies very largely outside and beneath that of ordinary zoological and even botanical thought, though every botanist may teach its first elements. Its medical and even its economic interests have each evoked their own specialists; and it is interesting that these new groups of experts differ not a little from us older naturalists, and even from each other, in their ways of work and thought, evolving not only techniques of their own, but theories and speculations too. And though some protistologists have been struck by the resemblance of flagellate bacilli to certain very simple flagellate infusorians, and mycologists have often endeavoured to connect bacteria with fungus moulds, whether as degenerate forms or

ancestral ones, there is little evidence for either view; there are bacteria in Carboniferous times or earlier, yet essentially like our familiar ones. Indeed, we cannot but suppose those of decomposition to be as old as any higher life-forms, since otherwise dead animals and plants would have accumulated beyond space for living ones. Nor have they been mere saprophytic agents of the decomposition of organic forms, as we naturalists mainly think of them; nor yet simply also parasitic, as surgery and medicine have to deal with them; but also, from a long past (perhaps before the advent or abundance of higher organic life) in forms of independent and self-sustaining existence; and this even as mud-forming and thus in time rock-forming agents, and on what by some is considered a colossal scale in the early past, and not without corroboration from such forms and their operations observed in progress to this day.

To ordinary nature-students, the single general conception suffices of the photosynthetic activity of green plants as fundamental, not only to their own existence, and to that of their plant parasites, and of the fungi and the bacteria of their decomposition, but, also directly or indirectly, to the nutrition of the entire animal world as well. Yet we are increasingly learning, from the bacteriologists, of very different and indeed independent modes of life-sustaining among forms of bacteria; and each of these is quite distinct from photosynthesis, indeed with light not utilised. The most familiar example of such distinctive physiological ways of life, for they are nothing less, is that of the teeming bacterial life within the root-nodules of leguminous plants (and a few others, e.g. alders) with their amazing powers of assimilating nitrogen from their soil atmosphere or soil water. For so far from robbing the plant of its nitrogenous substance, as ordinary bacteria and moulds do when it is dead and they decompose it, this bacterial activity, going on within these nodules, richly endows their host-plants: and so enables us to understand their usually exuberant growth and flowering; and, above all, that exceptional proteid wealth of their seeds, so superior in nutritive values to those of the cereals as to render them, for vast Oriental populations especially, the established substitute for the costlier milk, eggs, fish, or meat demanded by Western peoples; and thus rendering even the strictest vegetarianism perfectly healthy and practicable.

Again, the bacteriologists of soils are now familiar with other nitrogen-utilising types, free-living, and quite distinct from those symbiotic with leguminous plants. Upon these agriculture is yet more substantially dependent. They are known as nitrite- and nitrate -bacteria respectively, the former utilising salts of ammonia from the soil, and leaving nitrites, which the next group then oxidise to nitrates, which can then be taken up in solution by the roots of plants. Each form, of course, keeps such nitrogen as it needs, and

gets its carbon from carbonic acid; yet this in darkness, and so by some other process than that of the green plant.

Here we must not make too much of the distinction discovered by Pasteur between aërobic and anaërobic fermentative organisms. The former are dependent upon accessible free oxygen, like the animal world, and ordinary plants as well, not even excepting the leaf in active photosynthesis; but the latter are independent of free oxygen, and even inhibited or killed by it, though wresting their needed oxygen from such of its compounds as they can attack. For this mode of life Pasteur found in various yeasts as well as in bacteria; and biochemists have recently made notable advances in explaining the processes of oxidation and reduction in the tissue-life of higher organisms, though these, of course, also as a whole continue respiring in the ordinary way. (See Cell Oxidations.) Still, it is among bacteria that we find this anaërobic process most frequently, and then usually, though not invariably, as an essential condition of life.

The protean physiology of bacteria, beyond that of plants and animals, is already illustrated in so many ways that we may well be on the outlook for more of them. "Iron bacteria" have been described, yet remain dubious; but there is no doubt of the "sulphur bacteria" which utilise sulphuretted hydrogen, and accumulate granules of sulphur, which are believed to be reserves, assimilable as foodstuft. And among these sulphur bacteria, some have a purple pigment which enables them to utilise light-energy, in analogy to green plants, yet probably not closely so. There are other bacteria which can grow in air, and on ordinary media like most others, yet also utilise hydrogen directly; others can decompose marsh gas (CH_4) as green plants do CO_2, and yet others which can even thus utilise the carbon monoxide so deadly to higher organisms. Here, then, within the so-called genus Bacillus, we have new fields undreamed by the ordinary vegetable or animal physiologist, yet now opening before the biochemist. The present point is thus confirmed; that here we are in a life-world widely and deeply different from our familiar ones, and expressing potentialities of physiological evolution beyond these altogether. Their adaptivity to environment, as shown by pathological and other research, is greatly beyond that of plants and animals, so here is indication of their distinctness from both. Furthermore, all this evolutionary potentiality and variety of functioning is practically unaccompanied by distinguishable changes in form; whereas in higher forms of life structure and function advance together.

Pass thus from these strangely varied ways of life, so often physiologically distinct from our familiar ones of animals and plants, with Protozoa and Protophytes of kindred life-processes, to their morphological aspect, so strangely simple, and so little differen-

tiated. We have been accustomed to extend the long familiar cell-theory, as the most fundamental and verifiable generalisation about the form of organic beings which we possess, to this bacterial world as well. But is this really sound, or safe? Not without modifying our ordinary and well-established conception of the cell, of which so much is known, despite its protean forms, changes and manifestations. In all ordinary cells we find also a nucleus, with broadly similar structure and behaviour, and these peculiarly characteristic, despite all minor differences, in cell-division; witness its predominant form, of complex mitosis. True, this complex division process is not invariable; direct division (amitosis) is also well-known; but after all only in special cases, and not as invariably characteristic of any metazoon or metaphyte, as a whole. At a time when the nucleus had not been made out in certain very simple Protozoa, Haeckel separated them from all other life-forms, as "*Monera*", and in distinction from all nucleus-possessing cell forms, as Endoplastica. In a number of these the nuclei were subsequently found, and so this distinction was dropped; yet exceptions still remain. Still these little affect the general importance of the presence or absence of the nucleus which we are emphasising here; save possibly to suggest some early phase of cell-evolution.

In the bacterial underworld multiplication by division has always been familiar, indeed at the most astonishing rates; yet here our high-power lenses and skilled eyes behind them, with application of every known microtechnique as well, have alike failed to confirm the (sometimes alleged) presence of any structure that can safely be identified as a true nucleus, with mitotic division behaviour, or even with amitotic; but at most only minute, and more or less indefinitely situated granulations. These can, indeed, be stained like nuclei, but they appear in mature forms rather than in the newest and youngest, whereas, were they true cells, it is there we should expect most clearly to make them out. Nucleo-protein substances are indeed found by the biochemist; but that is not to be wondered at, since bacteria partake of general protoplasmic nature. In all these ways, then, are we not being driven towards the conclusion that bacteria, albeit resembling cells in their multiplication by division, are yet of deeply inferior order to the cells proper of our ordinary biological experience? And if so, can we shrink from recognising bacterial life as a lower world altogether, deeply and remotely inferior to that of cell-life proper? In fact, may we not have to constitute a veritable Sub-Kingdom, lower by far than Protozoa and Protophytes? And since these, as truly cellular, are one with Metazoa and Metaphytes, shall we not have to call all these *Cellulares* (or some such name) and so relegate the bacterial world to a lower sub-kingdom altogether, described, say, as Pre-Cellulares?

FILTER-PASSERS.—Leaving now Bacteria as we see and know

them, what position are we to assign to that yet farther depth of underworld life, of which the existence has been demonstrated by the pathologist as the specific organic infections of various diseases, whose extreme minuteness is such as to pass through those finest of filters which arrest the minutest bacteria and their spores; and which thus long remained unseen with the highest microscopic powers? Yet in the case of the cancer infective organism, the brilliant investigation of Gye and Barnard, with the former's skill in culture and the latter's rare originality of microscopic device, has detected this; though still without attaining to adequate definition of form or structure, to which neither microscope nor ultra-microscope attains.

Yet here, and with other such filter-passers, the infective powers prove living activity; so we have to deal with a form of living matter which we cannot yet positively identify as belonging to the bacterial level of being. It may indeed prove necessary to assign to this a distinct character and position of its own, despite analogous variety and adaptivity of life-ways, as the various diseases caused by such infections show—witness smallpox, hydrophobia, foot-and-mouth disease, cancer, etc. Are we perhaps thus reaching down into a more or less completely precellular world, structurally at least below that of bacteria, as they below fully cellular organisms? It, of course, remains to be settled whether after all, as commonly supposed, these are not rather comparable to the minutest known micrococci and bacterium spores, and only minuter, by the degree which prevents their arrest by the filter; or perhaps divested of their resistant coating, and thus viscously passing through its narrow spaces. Yet when we take into account the measured dimensions of the smallest visible spores, and the far smaller apertures of the filter, do we not find an order of minuteness for these infection-bodies which begins to approach towards the (now approximately computed) magnitudes of protein molecules? If so, must not an aggregation of these be so small as to render even the simple bacterium-spore structure hardly, if at all, possible?

Be this as it may turn out, as investigation advances, there can now be no doubt that just as the ordinary microscopic research of naturalists has long revealed the cellular world in all ordinary life, though beyond ordinary vision, and just as the bacteriologist has gone yet deeper, so here we seem in the presence of a lower and minuter life-form still; and one bringing us nearer that of molecular structure and process, which the biochemist is not only analysing out, but even building up synthetically, in his own skilful and subtle ways. Among these minutest of life-forms, still so imperfectly known, is there not opening for him a new clue, even a new field of research, linking up the bacteriologist's and pathologist's with his own, and so with possible new light on the nature of life-processes, the building up of life-structures?

Just as at first among many medical minds, and still too popularly, Bacteria were mainly thought of in connection with disease, and even their ordinary decay-producing activities not sufficiently realised as beneficent, indeed indispensable, to living nature, so now we must guard against similar prejudice in regard to filter-passers, because those have mainly as yet come before us as concerned with peculiarly dreaded diseases. So here attention is needed to the remarkable work of d'Herelle on other filter-passers, which he terms "Bacteriophages", and for which he claims intensive germ-destroying powers. If so, the need of balancing our view of these lowest known forms of life as merely hostile to its higher forms must reappear for them as for Bacteria; at any rate so soon as our recent detection of some of them as baneful be complemented by the verification of d'Herelle's work, and perhaps even the extension and application of his views and hopes of them as antidotes

In summary, then, our argument is that thought and research throughout living nature require to be clarified a step below our prevalent acceptance of its physiological, morphological, and evolutionary unity, in terms of the cell-theory, a conception framed long before the days of bacteriology. In brief, though plants and animals (including simplest Protozoa and Protophytes)—the Organisata of Linnæus—are Cellulares, we may as yet limit off from these the underworld of bacterial nature, say, as Sub-Cellulares. And from this again, perhaps, the filter-passers as Pre-Cellulares. We do not suggest this classification for immediate adoption—for that the times are far from ripe; we merely submit it as a suggestion towards discussion and inquiry.

THE DIFFERENTIATION OF UNICELLULAR ORGANISMS.—The Protozoa or Unicellular Animals include many classes well marked off from one another. They form a large phylum, perhaps a sub-Kingdom. They are conventionally contrasted with the multicellular animals or Metazoa—all the animals from Sponges to Man, all the animals with a "body". This "body" is built up of many cells or modifications of cells, and even a very small animal, like a Rotifer, that can pass through the eye of a needle, may have a thousand cells. Now a cell, in this connection, means a unit-area or corpuscle of living matter with some measure of individuality ("a life of its own"), and consists, typically, of a minute mass of cell-substance or cytoplasm with a chromatinic nucleus as its vital centre. But while it is perfectly clear that the body of a Metazoon can be analysed into a multitude of component "cells", it is not so clear that we should call Protozoa "single cells". It is true in one way, misleading in another. For the Protozoon is an organism, an autonomous creature, complete in itself. As Dr. Clifford Dobell has vigorously insisted, a false note is struck when we speak of the

Protozoa as single cells. They are rather non-cellular than unicellular. They are organisms, often very intricate, often with elaborate beauty, often very adventurous, which have elected to do business on a bodiless basis. To what are they comparable but to the germ-cells of bodied animals—organisms telescoped-down to a unit expression? With this proviso, one may continue to speak of the Protozoa as single cells.

One of the great eras in Organic Evolution was that during which the forms of unicellular life became differentiated, and the path of differentiation they have not ceased to pursue. In protean variety there arose among the Protozoa and the Protophyta many different types, often with little in common save that they were single cells complete in themselves.

THE CELL CYCLE.—When we avoid the complexity involved in a systematic classification of the Protozoa, and try not to lose sight of the wood in the trees, we may discern three main pathways in the evolution of the group, of which a general interpretation was offered many years ago by one of us, in terms of the conception of "the cell-cycle".

Some of the simplest Protozoa, or organisms antecedent to the Protozoa, namely, the Proteomyxa and Myxomycetes, pass through a cycle of phases. A flagellate spore may sink down into an amœboid unit; a number of amœboid units may coalesce to form a composite amœboid plasmodium; a part of the plasmodium may encyst and divide into minute units which escape as flagellate spores. Here, then, is a cell-cycle showing a passage from flagellate to amœboid, from amœboid to encysted, from encysted to flagellate again, the plasmodial phase being interpolated as an additional chapter. This is the primitive cell-cycle, and there are many illustrations of it. The Protozoa show a tripartite grouping—the very active, predominantly katabolic Infusorians, the very sluggish, preponderatingly anabolic Sporozoa (in particular the Gregarinids), and the more or less amœboid Rhizopods between—on a *via media* between the two extremes.

The unifying idea thus suggested is simply that the Infusorians, Rhizopods, and Sporozoa, the three great classes of Protozoa, are, as it were, the respective accentuations of the flagellate, amœboid, and encysted phases in the life-history of the simplest. Moreover, each often shows traces of other phases besides that which it mainly represents. Thus an Amœba often passes into an encysted state, a young Radiolarian may be flagellate, a young Sporozoon may be flagellate or amœboid—partial expressions of the primitive tendency to a cell-cycle.

To adduce as an objection to this idea the fact that our once single class (or order!) of Infusorians has been, with increasing

knowledge on the part of its investigators, exalted to the rank of a sub-phylum with several classes, is rather to miss the point, which is merely to indicate the main pathways of evolution. The multiplication of pathways, both divergent and parallel, is a more detailed question of pedigree. The general idea is that the pathways trend in three main directions, of which the flagellate, amœboid, and encysted phases in the life-cycle of Protomyxa or the like, are, as it were, far-off finger-posts. That the Ciliata are far more highly evolved organisms than the Flagellata is not inconsistent with regarding both as in an evolutionary sense Infusorians.

But what gives fundamental importance to the idea of the cell-cycle is the fact that the three lines—(1) flagellate (and ciliated), (2) amœboid, (3) encysted—correspond to the three physiological régimes: (1) of lavish expenditure, "living dangerously", relatively high katabolism; (2) preponderant storing, a life of ease, relatively high anabolism; and (3) a balance or compromise between these two extremes. It is interesting to observe that a flagellate spore may become amœboid as its income and savings increase, that a Sporozoon which gives off amœboid processes at the beginning of its life soon becomes corticate and without locomotor processes. That this may be adaptive to circumstances is not inconsistent with its being physiologically necessary.

The general idea of the cell-cycle is corroborated by observing how it fits in some measure for the cells of multicellular animals. For there we find (1) some very active cells, notably ciliated epithelium, or, say, the collared flagellate cells of Sponges, the "flame-cells" of Flat-Worms and the "solenocytes" of Annelids; (2) amœboid cells, like white blood corpuscles, phagocytes, and osteoclasts; and (3) very sluggish cells, like fat-cells and cartilage cells. In certain cases, moreover, the transitions of the cell-cycle are still echoing, for a flagellate endoderm cell in the food-cavity of Hydra may become amœboid in tackling a small organism that has been ingested; and in a kind of "sore-throat" the ciliated cells lining the windpipe sink down to an amœboid phase—a far-off recapitulation of a chapter in the life-history of the simple Protomyxa. There is no contractility or external mobility in the fully developed nerve-cell, but it is a very interesting fact that during the development of a fibre the tip probes its way in the primeval amœboid fashion.

Other illustrations may be found in the germ-cells. The young ovum is often amœboid, that of Hydra being a fine example, and young germ-cells in Hydrozoa often migrate in the body for considerable distances. The mature ovum, however, often rich in reserves, is a characteristically encysted cell. A typical spermatozoon with its locomotor "tail" is in this wide sense flagellate; the aberrant sluggish spermatozoa of most crustaceans and threadworms are correspondingly of amœboid phase. That the "encysted" ripe ovum

and the "flagellate" ripe spermatozoon are also adaptive in their contrasted characters, is not inconsistent with seeing in these characters alternatives of cell-life which found expression in the primordial organisms.

In developing as well as in fully formed tissue there are illustrations of the deep-seated tendency to three main cellular possibilities —flagellate or ciliated, encysted, and more or less amœboid, and to a passage from one to the other. In the interpretation of pathological changes the idea of the Cell-cycle seems to be of value. More than that, in the great dichotomies or trichotomies of Organic Evolution, the fundamental alternatives of the Cell-cycle reappear in many a guise.

BEGINNINGS OF REPRODUCTION.—It is instructive to search among the unicellular organisms for the beginnings of reproduction and sex. There are some Protozoa, e.g. Schizogenes, where the division of the cell is not far removed from breakage; and the giving off of multiple buds in the Rhizopod Arcella is also very primitive. The division of a unicellular organism into two is usually preceded by the division of the nucleus, but in Bacteria that vital centre can hardly be said to have been differentiated. In some Amœbæ the nucleus divides in the simple or direct (amitotic) fashion, constricting into the form of a dumb-bell and then breaking across the narrow isthmus; but other Amœbæ show the complicated manœuvres of indirect or karyokinetic (mitotic) nuclear division. Many nuclei may be formed in limited time (one following another in rapid succession) and in limited space (within the wall or the cyst of the parent cell); and this results in spore-formation.

On another line, leading to fertilisation, one may distinguish many gradations. In plasmodium-forming there is a flowing together of exhausted cells; some cases of multiple conjugation of similar units are known; in ordinary total conjugation there is a union of apparently identical cells (isogamy) as in two Gregarines, or there is the combination of a macro- and a micro-gamete, as in the malaria organism (Plasmodium), or in the common Bell Animalcule. On a special path is the partial conjugation, characteristically complex in Ciliate Infusorians, like Paramœcium, where there is dimorphism of nuclei; and an exchange of micronuclear elements between the two conjugants, after which they separate.

A very interesting detail is the occasional occurrence of a nuclear reduction before the two unicellulars (or their special gametes) unite, for this is analogous to the nuclear reduction (e.g. polar body forming) in the gametes of multicellular animals. This nuclear reduction is seen in some Ciliate and Flagellate Infusorians, and in some Sporozoa and Heliozoa. When the spherical sluggish macrogamete in the life-history of the malaria-organism is fertilised, after

nuclear reduction, by a minute motile microgamete, the occurrence is evidently not very different from the fertilisation of a Metazoan egg-cell by a sperm-cell. And the anticipation becomes even more marked when a Protozoon colony, as in some Radiolarians, produces special dimorphic gametes which unite to form a zygote—the starting-point of another colony. In short, there remain many indications of the primitive steps towards multiplication on the one hand and sex on the other.

THE MULTICELLULAR BODY.—It was a step of far-reaching importance when many-celled organisms began, when Metazoa and Metaphytes appeared on the stage previously confined to the Protozoa and Protophytes. What light do existing forms throw on the bridging of the gap between unicellulars and multicellulars, which Agassiz called "the greatest gulf in organic nature"? The clue is probably to be found in those Protozoa and Protophytes which form loose colonies of cells. Thus the spherical green colony called Volvox, of 1,000 or even 10,000 cells according to the species, is a pinhead-like "body", often formed by the division of a fertilised macrogamete, practically an egg-cell. It inclines in some ways to the plants, and is often claimed by the botanists; but there are also many emphatic Protozoon colonies, e.g. in several orders of Radiolarians, and some of them are the size of split peas. What has happened in such cases is that the daughter-units, formed by division of the original cell, have remained associated, instead of drifting apart in individual completeness. Out of this weakness—if it was a weakness—strength arose, the strength of animals with a body.

Another possible mode of origin is by repeated division of the nucleus, without corresponding division of the cytoplasm, and there are many multinucleate Protozoa, such as the giant Amœba (Pelomyxa), large enough to be cut into two with a scalpel, and the beautiful ciliate Opalina that lives in the frog's intestine. If some cytoplasm should gather round each of these nuclei, as happens in the division of many ova which pass through a "syncytial" stage, a multicellular body might result.

It is probable that various experiments were made in body-making. Thus in some simple colonial Algæ, like Gonium, a platelet of cells is formed—the so-called placula; in other cases, e.g. the rather dubious Proterospongia, the incipient body is an irregular blob or parenchymula, with amœboid cells in an internal gelatinous matrix and collared flagellate cells round the margin. Yet in all probability the successful tentatives in body-making took the form of hollow balls of cells, one layer thick (monoblastic), whence, at a subsequent stage, two-layered (diploblastic) gastrula-like types arose.

Here some reference should be made to the small and somewhat

heterogeneous group of Mesozoa, e.g. Dicyema, Rhopalura, and Salinella, which occupy a midway position between Protozoa and Metazoa. Some are of great simplicity; thus Salinella consists of a single-layered tube of ciliated cells, open at both ends; but the majority are parasites, and it is therefore possible that their simplicity is in part retrogressive, not primitive.

NATURAL DEATH.—On the acquisition of a body a penalty was imposed—namely, Natural Death. In other words, the Protozoa seem to enjoy cellular immortality. From time to time, nowadays, they exhibit symptoms of wear and tear and loss of vigour, periods of physiological "depression", as it is called; but in natural conditions they rally and continue as before insurgently—moving, feeding, growing, and multiplying. Hence Weismann's striking phrase—"the immortality of the Protozoa".

Here a distinction must, of course, be drawn between the three chief kinds of death. (*a*) If death be the irrecoverable cessation of protoplasmic activity, one of its commonest forms is *violent*, as when the organism or some important part of it is shattered or devoured, frozen, or dried up. Most living creatures die a violent death, and from this there is no exemption for the Protozoa, or for any other unicellular form of life. They may be crushed, smothered, devoured, and so forth, though their minuteness is perhaps of some survival-value. It is probable that vicissitudes of temperature account for the death of the countless myriads of unicellulars which sink slowly from the surface to the floor of the sea, where they form the fundamental food-supply of abyssal animals. In any case, Protozoa are certainly not exempt from violent death.

The second kind of death is *microbic* and *macro-parasitic*, when the organism is disintegrated or punctured or poisoned by virulent intruders. These may be Bacteria, as in plague and tuberculosis; or aggressive Protozoa, as in Malaria and Sleeping Sickness; or multicellular intruders, such as Hookworm and Bilharzia. The damage done by the invaders is varied; it may be a breaking down of tissue, or a choking of narrow passages, or a making of punctures; but the commonest injury done by the small forms (microbes) is of the nature of poisoning. Thus the malaria parasite (Plasmodium) destroys red blood corpuscles; but in so doing it liberates toxins into the circulation. Death due to microbes or to larger intruders is very common in man and in his stock, partly because of the artificiality of the conditions of life, and partly because of the frequent lowering of powers of resistance, e.g. the vigour of the bodyguard of amœboid cells or phagocytes, which are normally useful in engulfing and digesting intruding Bacteria. In Wild Nature microbic disease is very uncommon, and even such cases as a bacterial disease in sandhoppers, and another in salmon, may be associated with

some artificiality in the environment. As regards the abundance of larger parasites in many animals, there is no doubt that a live-and-let-live compromise has often been reached between host and guest. The grouse always contains hundreds, if not thousands, of minute, almost transparent, threadworms in its intestine, but these are not known to be of serious moment unless the vigour of the bird is diminished by prolonged bad weather, insufficient food, overcrowding and its consequences. Then the multiplication of the previously unimportant threadworms, along with other parasites, may become prodigious and fatal.

How do Protozoa stand as regards the attacks of virulent microbes? Experiments have shown that some Protozoa are well able to ingest and digest microbes, and some, such as certain species of

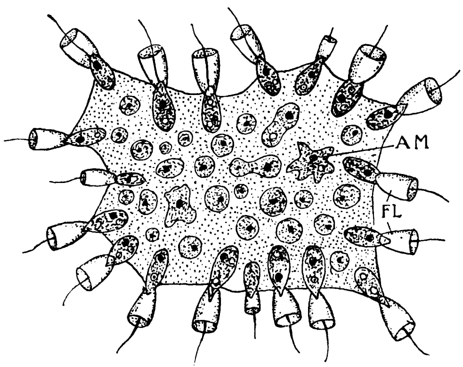


FIG. 146.

A Colony of Flagellate Infusorians, *Proterospongia hæckelii*. After Saville Kent. There are about forty flagellate individuals (FL), each with a nucleus, a wineglass-shaped collar, and a flagellum or lash. In the internal gelatinous matrix there are amœboid individuals (AM), some of which may be seen in process of division. This may be one of the descendants of transitional forms between Protozoa and Metazoa.

soil Amœbæ, feed largely on Bacteria. This points forward to the microbe-destroying function of the wandering amœboid phagocytes which are present in most multicellular animals. To some extent, then, Protozoa can resist microbic death.

Natural Death is due to the slow mounting-up of unrepaired results of vital wear and tear. Living implies a transformation of energy within a material system, and some structural disintegration is inevitable. This, as everyone knows, is counteracted by processes of recuperation, as afforded by food, rest, sleep, and change. All the recuperative influences may be summed up in the concept of *rejuvenescence*—keeping the body young, or making it young again after some exhaustion. From youth onwards these operate against the processes of *senescence* or ageing, the inevitable consequence of any failure to make good the wear and tear. The more complicated the structure of the body—which some are too fond of calling its

"machinery"—the more difficult is it for rejuvenescence to keep pace with senescence, especially as regards hard-worked organs. In a higher animal these hard-worked organs are especially the liver, the kidneys, the heart, and the brain—to put them in their probable *average* order of overwork. Hence the frequency of breakdown in these organs!

Natural Death was the price paid for a body, or for one much worth having; and the Protozoa are largely free from this limitation of all other life, because the whole organism is so relatively simple and so readily amenable to recuperation. Wear and tear are continually made good. Apart from their recurrent "depression" states, the Protozoa are able, in their normal environment, to sustain with persistent success the vital equation between waste and repair.

The second reason for the relative immunity of the Protozoa from Natural Death is the simplicity of their modes of multiplication. Some of the sea-worms burst in liberating the germ-cells; many insects, such as butterflies and Mayflies, die immediately after reproduction; even strong muscular animals, such as sea-lampreys and common eels, do not seem to recover, in either sex, from the exhaustion of producing and liberating the sex-cells. But it is otherwise with the Protozoa. For a Protozoon divides into two or into many in a relatively simple way which cannot be called physiologically expensive. The parent organism is directly continued in its progeny, and we can hardly speak of death when there is nothing left to bury.

A multicellular body had several advantages, such as greater possibility of division of labour, greater possibility of attaining a certain momentum of size and vital capital; and it was the beginning of the important distinction between *somatic cells*, forming the body, and *germ-cells*, continuing the race. This is clearly seen in the Volvox colony, where, in a variety of gradations, there is a setting apart of specialised germ-cells within the hollow ball. But what we have been indicating from the evolutionist point of view is that this great step of body-making was associated with the first appearance of Natural Death, which, while probably inevitable, was probably justified by lessening the risk of multiplying when senescence was dominant.

THE ORIGIN OF SEX.—We have already referred to the gradations among the Protozoa which lead to the fusion of two dimorphic reproductive units, one relatively more anabolic, the other relatively more katabolic. In the Bell Animalcule (Vorticella) a small free-swimming unit, which might be called male, penetrates into a fixed individual of normal size, which might be called female (Fig. 57).

It was doubtless by colonies of unicellulars, or by some simple forms of Metazoa or Metaphyta, that another step was taken,

namely the separation between special reproductive cells or germ-cells and the ordinary somatic cells or body-cells.

A third step was the distinction between individuals producing ova and others of the same kind producing spermatozoa. This was the beginning of sex in the strict sense; and it is well illustrated by Volvox, which we regard as a colony-forming Infusorian, though it is sometimes claimed by the botanists as a free-swimming fresh-water Alga. It is a beautiful gyrating hollow ball of green biflagellate cells, connected by fine protoplasmic bridges and embedded in a gelatinous matrix, from which their flagella project. In *Volvox globator* the average number of individual units is about 10,000; in *V. aureus* or *minor*, 500–1,000. Each cell contains a nucleus, a contractile vacuole, and chlorophyll corpuscles, which enable Volvox to feed holophytically, i.e like a green plant. At the anterior hyaline end of each cell, where the two flagella are inserted, there is a pigment spot, which has probably some orientating function.

In its method of reproduction Volvox is of much biological interest and importance. As Klein, one of its best describers, says, it is an epitome of the evolution of sex. Some of the colonies are asexual. In these a limited number of cells possess the power of dividing up to form little clusters of cells; these clusters escape from the envelope of the parent colony, and form new free-swimming colonies. In other colonies there are special reproductive cells, which may be called ova and spermatozoa (Figs. 147–149).

In *V. globator* the two kinds of reproductive cells are usually formed in the same colony, the formation of spermatozoa generally preceding that of the ova. Technically the colony may then be described as a protandrous hermaphrodite.

In *V. aureus* the colony is oftenest unisexual or diœcious, i.e. either male or female. But it is sometimes monœcious or hermaphrodite, and in this case it is generally protogynous, i.e. producing eggs first.

Whether in a hermaphrodite or in a unisexual colony, the sex cells appear among the ordinary vegetative units; the ova are distinguishable by their larger size, the "sperm mother-cells" divide rapidly and form numerous (32–100 or more) slender spermatozoa, each with two cilia. In *V. globator* their bundles may break up within the parent colony; or, as always occurs in *V. aureus*, they may escape intact, and swim about in the water. In any case, an ovum is fertilised by a spermatozoon, and, after a period of encystation and rest, segments to form a new colony. Occasionally, however, this organism, so remarkable a condensation of reproductive possibilities, may produce ova which develop parthenogenetically.

Here, then, we have an organism, on the border-line between plant and animal life, just across the line which separates the unicellular from the multicellular, illustrating the beginning of that important distinction between *somatic* or body cells and *reproductive*

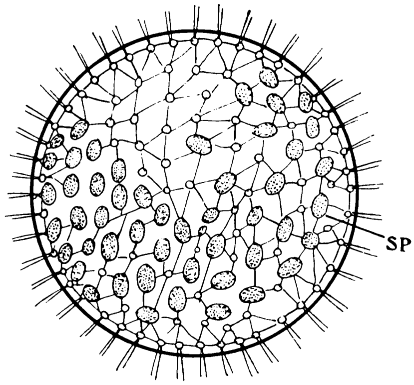


FIG. 147.
Male Colony of Volvox, with numerous sperm-producing cells (SP).

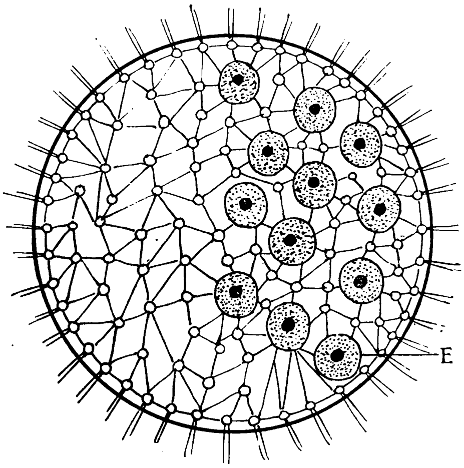


FIG. 148.
Female Colony of Volvox, producing numerous egg-cells (E).

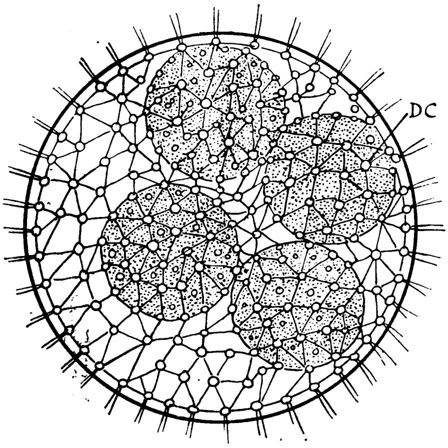


FIG. 149.
Colony of Volvox, containing four daughter colonies (DC).

cells, and occurring in asexual, hermaphrodite, and unisexual phases. Klein records no less than twenty-four different forms of *V. aureus* from the purely vegetative and asexual to the parthenogenetic, for there may be almost entirely male colonies, almost entirely female colonies, and other interesting transitional stages. Klein has also succeeded to some extent in showing that the occurrence of the various reproductive types depends on outside influences.

INTERNAL CAVITIES.—One of the obvious differences between typical plants and typical animals is the absence of well-defined internal cavities in the former. No doubt there are air-cavities in leaves and capillary vessels in wood, but apart from a few highly specialised cases like Pitcher-plants, there is nothing that can be compared to stomach, lungs, or heart, or other internal cavities characteristic of animals. Plants are in this respect vaguely comparable to sponges, where there is no food-canal in the strict sense, its place being taken by the usually intricate system of inhalant and exhalant canals.

From Hydra and its relatives onwards there is a food-canal with a mouth, a distinct step as compared with a colony of Protozoa, where the food-capture is on the surface. But given a gut or enteron, lined by cells which are the first to be fed, we can readily picture the disproportionate increase of this internal cavity and the origin of folds and pouches, which afford opportunity for all sorts of division of labour. It is interesting to picture the long succession of gut-outgrowths in, say, Vertebrate animals—the gill-pouches, the thyroid diverticulum, the swim-bladder or the lungs, the liver, the pancreas, various cæca, and the allantois. It has been a characteristic line of advance—to increase internal surfaces. The possibilities include more than an increase in the number of different pouchings; there may be great increase in the internal surface of an individual pouch. Thus the lungs of birds, though small and inexpansible, are particularly effective lungs, and partly because of the great increase in their branching internal surface, not to speak of the extensions of air-sacs into the body-cavity, sometimes into the very bones.

When animals left the water and began to colonise dry land, one of their difficulties must have been that while oxygen was more abundant, it was less available, especially when the surface of the animal became protected by cuticle and shell and the like. One of the ways of meeting this difficulty was the enormous increase of internal air-conducting surfaces, as seen in the tracheæ of insects and their relatives. This requires fuller illustration.

INCREASE OF SURFACE.—Part of the secret of an average insect's great activity is surely to be found in the fact that the blood does not become appreciably impure. This is because the blood is always near some branch of the system of air-tubes or tracheæ, which

ramify into every organ and corner of the insect's body. In most other animals the blood goes to the air, either on the skin or on the gills, or on the walls of the lungs; but in insects the air goes to the blood. These air-tubes have a very large internal surface, and interchange of gases with the blood is thus facilitated. Similarly, as above mentioned, birds' lungs have a very large internal surface on which the blood-vessels are spread out. The feathery gills of the lobster have likewise a very large external surface on which the blood is exposed to aëration, as on a country with a big coast-line. The absorption of digested food from the small intestine is facilitated by the immense surface afforded by the microscopic finger-like processes or villi which line the interior. People who go to live at hill stations or at Johannesburg (about 6,000 feet above the sea) mostly soon show a great increase in the number of their red blood corpuscles. This is a very useful adaptation; for it means that at altitudes where oxygen becomes appreciably scarcer there is compensatory increase in the aggregate surface of the oxygen-capturing red blood corpuscles.

In breaking up the soil, whether this is effected by ploughing or clod-crushing, or whether the agency be earthworms or frost, is not the result an increase of surface in the soil, or among the soil fragments, an increase which promotes, to take the simplest issue, the solution of salts, thus affording more food for the roots of plants? In increase of surface, again, is the significance of the multitudinous leaves of the grasses, which do not get in one another's way, and the value of cut-up leaves. A large tree may be exposing a leaf surface of more than an acre. And even this is understating the fact, since the essential photosynthetic process takes place in the spacious interior of the leaf. For here again the amount of surface counts for much, not only because that of the innumerable cell-walls is very important, but because the starch-grains may be seen forming within the minute chlorophyll bodies, which again offer an exceedingly large surface to light.

Perhaps a critic may say we are over-emphasising the superficial; yet we cannot but press the simple thesis that one of the great lines of organic evolution—from the colloidal amœba to the cerebral cortex of man—has been to—and through—more surface.

BILATERAL SYMMETRY.—It was in some simple worm-types, like Planarians, that bilateral symmetry was first firmly established among multicellular animals; and it was undoubtedly a great step in evolution. Except in a few cases, like adult sea-urchins, it was not afterwards departed from; for even in the large class of snails or Gasteropods, the radical lop-sidedness is a disturbed bilaterality. A radially symmetrical animal like a jellyfish can move indifferently in any direction in the sea; and though the concave surface of its

disc must always be ventral or posterior to the direction in which the creature is swimming, one cannot distinguish head and tail ends, nor right and left sides. Bilateral symmetry implied that one end of the body always took the lead in locomotion, and this was doubtless advantageous in pursuing food, avoiding enemies, and chasing mates. Its acquisition had far-reaching consequences, which include our knowing our right hand from our left.

BEGINNINGS OF BRAINS.—Very careful investigation of the minute structure of sponges has not furnished any trace of nerve-cells, and this defect is enough of itself to account for the fact that sponges do not seem to lead on to any other type of animal, but represent a blind alley in organic evolution—albeit often a very beautiful one.

Among Cœlentera or Stinging Animals, such as sea-anemones and jellyfishes, there are numerous nerve-cells more or less diffusely distributed. A common state of affairs is that found in sea-anemones, where there are superficial sensory nerve-cells connected by fibres with a loose network of ganglion-cells. These lie beneath the skin and give off motor fibres to muscle-cells. The essence of a nervous system is here, and if the tentacles on one side of the sea-anemone are stimulated repeatedly by faked food they cease to respond, having learned a simple lesson. Yet the tentacles on the other side of the sea-anemone may then be cheated, as Prof. G. H. Parker has shown. In other words, the experience enregistered in the neurons of the one side of the body does not affect the behaviour of the neurons on the other side. This illustrates in a simple way one of the advantages of having nerve-centres or ganglia.

Beginnings of ganglia are found in some Cœlentera, but it is to simple worms that we must look for the first appearance of "head-brains", which may be associated with the acquisition of bilateral symmetry. If a polarity had been established so that one end of the body always took the lead in locomotion, it seems reasonable to suppose that nerve-cells would be most developed in that much-stimulated, and otherwise over-educated, head region. Variants that wasted an abundance of nerve-cells on less strategic points would tend to be eliminated. Moreover, bilateral locomotion in early stages, with consequent frequency of stimulation at the head end, would tend in the individual lifetime to evoke the nervous initiatives or factors in these anterior cells. Thus, as a brain always develops from the sinking in of ectodermic cells from the surface of the embryo, its evolutionary beginning in the head-ganglia of simple worms is in part explained. A head-ganglion became worthy of the name of brain when it was not only the chief sensory centre (receiving tidings from without and from within) and the chief motor centre (issuing orders to muscles and glands), but also the chief co-ordinating

centre (combining a succession of activities into an effective sequence). Given a ganglion, there is greater efficiency in storing, shunting, combining, and inhibiting nervous impulses; given a brain, there is the beginning of a higher grade of behaviour, and the beginning of the emergence of mind. The centralising of the nervous system, often re-effected, was the main method of progressive integration of life; and it evolved hand in hand with improvements in the sense-organs.

STEP BY STEP.—But our object in this book is merely to illustrate and suggest, and we can only select here and there from the long series of steps of great evolutionary significance.

How important it was when a body-cavity fluid was replaced or supplemented by a definite blood circulating in vessels! The blood forms a common medium of the body from which all the cells take and to which they all give; it carries digested food and captured oxygen to the tissues; it sweeps away carbon dioxide and other poisonous forms of waste; it distributes phagocytes and anti-toxins and hormones; it secures a chemical balancing of the salts in the body—salts whose history leads us back to the composition of a pre-Cambrian sea.

What acquisitions were implied in having a segmented or metameric body and in gaining paired limbs! How interesting are the two or three hints among Invertebrates of hormone-making cells and the momentous specialisations of these in the various endocrinal glands of Vertebrates!

One of the greatest steps was the origin of Vertebrates—a step still wrapped in almost complete obscurity. What a series of advances they have made in hundreds of millions of years! After the supporting skeletal axis came the skull, and after the skull the jaws and the paired limbs. Long afterwards we discern in pioneer amphibians the first digits and lungs and voice.

How momentous the adventure—several times repeated—of leaving the water for the dry land, and leaving terra firma for the air and the trees! Of far-reaching importance also were the several tentatives towards viviparity, which eventually found its best expression in mammals.

But take two or three instances in more detail to illustrate the value of adding to the more familiar and conventional retrospect of racial evolution an envisaging of the great steps and their consequences.

SOME OTHER GREAT ADVANCES IN ORGANIC EVOLUTION

THE ORIGIN OF LAND PLANTS.—The more one thinks about the conquest of the dry land by adventurous animals of aquatic

ancestry, the more convinced one becomes of the impossibility of success if plants had not led the way. Plants ensured the food, the moisture, the shelter, without which the dry land would have been altogether too inhospitable for animals. Thus the problem of the origin of land plants has an enhanced interest.

It seems quite certain that many ages passed before there were any land plants at all. In Cambrian, Ordovician, and Silurian strata there are plenty of traces of seaweeds; but there are no known fossil land plants before the Devonian. Among the earliest are the very interesting Devonian fossils discovered at Rhynie in Aberdeenshire. Of course it is quite possible that there may have been pioneer land plants long before the Devonian, but of a type too simple to admit of definite fossilisation.

The general view in regard to the origin of terrestrial plants is something like this: the simplest plants began in the sea and flourished there for ages; but some of them, obedient to the universal impulse to press into empty corners, made their pioneering way from shore to estuary, from estuary to river, from river to lake, from lake to swamp and marsh, and thence, at last, began to colonise the dry land. At each station in their ascent some would no doubt settle down and specialise as best they could in relation to the immediate environment, while others would spread onwards, trying, as it were, to find something better. Whether some may not have passed directly from the seashore to the shore-marsh, and thus on to dry land, without serving an apprenticeship in the fresh waters, is a question in detail which may be waived for the present. But the general idea thus sketched is that relatively simple plants, endowed with considerable migrating power, like many of the unicellular algæ, did the exploring; and that structural evolution might well advance in the successive stations where they established themselves. One must remember that detached propagative parts of plants would not readily migrate upstream, though spores might be borne by the wind. Fishes may have helped in transport, but there were no plant-distributing birds in those early days. Moreover, there were no true seeds before the Devonian. The general idea seems to be that very simple plants did the travelling; and that, when they reached suitably moist terrestrial resting-places, they proceeded to evolve into organisms like our liverworts, mosses, and ferns, building up structural complexities somewhat similar to those that had already been achieved among seaweeds in salt water, similar yet different, being adapted to the quite novel conditions of terrestrial life. In his *Origin of a Land Flora* (1908), Bower has sought to show how the exaggeration of the spore-bearing (sporophyte) generation and the repression of the sex-cell-bearing (gametophyte) generation, which is so characteristic of all flowering plants, would follow as a natural outcome of becoming terrestrial. But the prior question is

how the transition from aquatic to terrestrial (or subaërial) conditions may have been effected.

Another contribution to the problem of the origin of land plants has been given by the distinguished Oxford botanist, Dr. A. H. Church, in an essay entitled *Thalassiophyta and the Subaërial Transmigration* (Oxford University Press, 1919), an essay as full of suggestive ideas as it is of difficult terms. Dr. Church's general idea is that terrestrial plants arose by the gradual transformation of highly evolved marine plants on a slowly rising beach. Transmigration for him means "transition *in situ*". "When the first land gradually lifted above the primal sea, bearing all forms of marine life on it, the successful transmigrant algæ of the first land migration combined the best and highest factors of marine equipment." What had been gained in the sea in the course of ages was not lost, to be invented *de novo* a second time; it was adapted. It was not in the reproductive part of the plant that the profoundest changes were necessary; it was the body that required to be readjusted, from life in an aqueous food-solution to life in an atmospheric medium, with no external food-solution beyond that absorbed by the roots.

After the gradual cooling of the earth there were, according to Dr. Church's picture, three great epochs of world-construction, with associated vegetations. There was the time of the condensation of water-vapour to form the sea, which he supposes to have covered the earth, and the surface-waters of that sea were peopled (as still so much to this day) by microscopic plants sufficient unto themselves. This was the Plankton Epoch. Second, the folding of the earth's crust raised parts of the floor of the sea within the reach of light, and minute plants began to settle there, anchoring themselves and proceeding to build up fronds and other forms of body. But anchoring on a substratum made it necessary to have some new arrangements to secure dispersal—a return to the plankton phase for processes of reproduction, much in the same way as we see in sponges which liberate free-swimming embryos, or in zoophytes which liberate swimming-bells or medusoids. A new note was struck: the types that survived were those whose individual members had moved in the direction of race-continuance—that most fundamental of all biological truisms. To the plankton law of self-preservation was added "the benthic law" of race-continuance. "The fact that any race still exists implies that the individuals collectively have done their bit." This was the Benthos Epoch, i.e. of plants still submerged. Third, there was the gradual emergence of land plants and the gradual transformation of aquatic vegetation—seaweeds for short—into a land flora, able to absorb gases from the air and salts in solution from the moist substratum. The Benthos life had introduced the new factor of substratum, but the emergence of the

land introduced the new factor of atmosphere. This was the Xerophyte Epoch. In other words, we must think: (1) of the primal Open Sea, with its free-swimming minute green plants; (2) of the floor of the illumined shallow sea with its anchored fronds, with new experiments in body-making on the one hand and in reproductive dispersal on the other; and (3) of the beach slowly rising, foot by foot, millennium after millennium, with its highly evolved seaweeds slowly adapting themselves into land plants.

"The energy of growth, at bottom a phase of chemical (ionic) activity, supplies the driving-power of life, and such 'life' beats against the sieve of Natural Selection; but this alone does not account for all the manifestations of plant-organisation. *Twice* in the history of the world the sieve itself has been changed: the 'hidden hand' which did this, and so determined the path to be taken as a sequence of progression, was not 'Nature' or 'Divine Guidance', except in so far as such expressions may be utilised to cover an inevitable march of events, in this case merely the expression of the cooling of the earth, which (1) lifted the sea-bottom, by tectonic changes, and (2) ultimately lifted the 'land' above the surface of the water, to be subjected to subaërial denudation to form 'soil'." Of course, only a few of the plankton creatures would get through the sieve to become anchored seaweeds on the substratum, and only a few of the benthic plants through the new sieve, to become the pioneers of a land flora. The idea of an evolution of sieves as well as an evolution of the sifted material is useful, but we should not be inclined to restrict the operations of the "hidden hand" to *twice*.

It is very impressive to visit a rocky foreshore at the lowest tide, to wade out among the Laminarian and other seaweeds not usually exposed at all, to observe the vigour and manifoldness of their growth and the complexities of their structure, and to realise that one is moving amid an antique vegetation, some members of which may be much older than the hills. The conventional view has been that these seaweeds represent a gorgeous blind alley; but Dr. Church compels us to consider the possibility that from among such highly evolved creatures the land flora may have emerged by gradual transformation as the foreshore slowly rose. This transformation cannot be thought of in any easygoing way. It meant that the seaweeds' gripping structures—mere holdfasts, not true roots at all—became provided with rootlets and root-hairs suited for the absorption of water and dissolved salts from the soil. It meant that a frond-surface adapted for the absorption of watery food-solution became fit for the absorption of the dry gases of the air. It meant the elaboration of a complicated vascular system, for conveying the raw materials and the elaborated materials from part to part. These are among the more readily stated of the difficulties which are faced—and ingeniously countered—by Dr. Church.

Many a plant is a very plastic or modifiable creature; and even such a stable structure as a tree, as notably the Bald Cypress (Taxodium), may adapt itself almost out of recognition to unusual conditions of life—moisture, drought, wind. etc. It may be that individually acquired modifications hammered on each successive generation of seaweeds on the rising shore, but never taking hereditary grip (for that would be Lamarckism!), served as life-saving screens until germinal variations in the same direction had time to establish themselves as appropriate somatic adaptations.

The migration theory of the origin of land plants, with which we started, is not an easy theory. Freshwater Algæ are rather of the nature of "depauperated relics". "To pass from the sea to fresh water implies starvation and deterioration of the output of reproductive cells, and hence failure to compensate the wastage of the race, and extinction." Perhaps this smacks a little of *ex parte* judgment; but there is the further difficulty of thinking of simple migrants from pond and swamp beginning *de novo* the elaboration of structural equipments which many of the seaweeds had already achieved. In place of this theory Dr. Church offers us "the epic of the stupendous epoch of a world-transmigration". "The cells and somatic organisation of all land plants, as also all their reproductive cycles and mechanism, are but the continuation of the mechanisms evolved in the sea, to suit the conditions of life in the sea, as the best response possible under such conditions; and though the mechanism may be emended, modified, or superseded in innumerable details, the primary plan of the architecture and the entire range of general principles of organisation remain essentially marine."

Such a view is in general idea in harmony with what we learn so often in the study of animal evolution, that apparent novelties are only very old structures transformed. New lamps out of old has been one of the great methods of evolution. And as to the maternal sea, its currents are flowing still in the life-streams of her children who have so long ago left her.

ORIGIN OF SEEDS.—One of the great steps in Organic Evolution was the origin of seeds. We take them now in a very matter-of-fact way, as if there had always been seeds, or as if it was easy to give an account of their emergence. Yet we meet few people who can tell us with any approach to clearness what a seed is, and what its significance in the life of plants. All that they are sure about is that seeds are detached from a parent plant and germinate into seedlings. Some will venture a little farther and say that a seed contains an embryo plant, that it has been sojourning for a time in more or less close union with its parent, and that it is in a strange state of arrested development or latent life, which may last for years.

In the Early Devonian Period, when the highest animals were fishes, there was a terrestrial vegetation. This is illustrated by the puzzling primitive Rhyniaceæ found by Dr. Mackie in a fossilised peat-bed at Rhynie in Aberdeenshire. Perhaps they linked the moss-tribe (Bryophytes) to the fern-tribe (Pteridophytes); they were in any case very simple and unique land plants. Later on, in the Upper Devonian, the land vegetation had made much progress, for there were many ferns and club-mosses, besides graceful Sphenophylls which have no living representatives to-day. It was about that time that Amphibians began to emerge, the distant ancestors of our frogs and newts. Now it was during this eventful time that there appeared the first plants with seeds; and they became numerous in the next period, that of the Coal Measures. The pioneer seed-bearers were for a long time regarded as ferns, to which they do not seem to be closely related, and they often get the name of seed-ferns or Pteridosperms. Perhaps a better name, though a longer, is Cycadofilicales, which suggests that they show a combination of fern-like and Cycad-like features. There is no doubt that they had seeds, though we have been told that investigators who have made microscopic sections have never found an embryo inside the fossil. These early seed-bearers, beginning in the Devonian, were exuberant in the Carboniferous, and they were eventually accompanied by cycads, conifers, and maidenhair-trees, showing us that we must correct or adjust the old description of the Carboniferous as "the Age of Cryptogams".

But while we are for the moment emphasising these primitive "Cycad-Fern" seed-plants, we must still picture the dense damp Carboniferous forests, whose debris formed the valued coal-measures of many countries, as mainly cryptogamic. Thus there were, besides ferns and tree-ferns, huge Lepidodendron club-moss-trees, such a contrast to their modern representatives, like the "stag's horn moss" on our moorland and the delicate Selaginellas in our greenhouse. There were Horsetails, too, rising to a stature of a hundred feet, such a contrast to our humble Equisetums by the roadside, or in the wood and the marsh. Yet there are glimpses of the distant æons in some American everglades of to-day where the horsetails far overtop the horse and his rider. We must not linger in the Carboniferous forests, but we cannot but mention the probability that some of the delicate Sphenophylls—unfortunately not included in the modern roll-call—were climbing plants, like so many in the tropical forests of to-day, or like the bindweed in our hedgerow jungles.

The exuberance of flowerless plants in Carboniferous forests has meant much to man, who has learned to use, for good and ill, the stores of bottled sunshine in the coal; but we are on a different line of thought just now. Our question is: What led to the seed-plant,

and how did plant-life attain to such exuberance before there were any seeds? The answer to the second half of the question is easy—we have only to shake one of these withering fern-fronds on a sheet of black paper. Then we see a shower of "spores", which used to be called "fern-seed". But they are altogether different from seeds, for they are single cells, as light as air, whereas seeds are embryo plants, usually well equipped with food and well protected by firm envelopes. But while we emphasise this fact, that the older flowerless plants, like mosses and ferns, multiplied themselves by unicellular spores, whereas the subsequent flowering plants multiplied by seeds, which already contain complex embryos when they are set adrift, there is in this a *suppressio veri* which obfuscates the whole problem.

For when the spore of a fern sinks to the moist soil, it develops, not into another fern plant like the parent, but into a small green disc or prothallus, which bears sex-organs. From the fertilised egg-cell of this unfamiliar sexual phase there develops the spore-bearing fern-plant we all know so well. This is alternation of generations, which is characteristic of the plant kingdom, and also occurs in a somewhat different way in some animal types, e.g. among the zoophytes, the Medusæ, the flukes, and the Tunicates. Its wide-spread occurrence among plants was discovered by the genius of Hofmeister, a botanical music-dealer, who left a deep mark on biological science.

The alternation is between an asexual spore-producing sporophyte, say the ordinary fern-plant, and a sexual gametophyte, like the fern-prothallus, producing eggs and sperms. From the fertilised egg-cell the sporophyte develops, and so the cycle continues. The sequence may be defined as the alternate occurrence in one life-history of two different forms differently produced. Of recent years it has been shown that the cells of the sporophyte, say the ordinary fern-plant, have twice as many nuclear chromosomes as the cells of the gametophyte, say the fern-prothallus. So it is a deep difference, though among some Algæ the two phases are superficially very like one another.

Alternation of generations began in the sea, and for millions of years all went well. But when some aquatic plants established themselves on land the gametophyte began to be badly handicapped. Thus one drawback was that the male-cell was suited for swimming freely in water and could not reach the egg-cell in any other way. Moreover, it is plain that the dry land does not afford such a safe and soft cradle for egg-cells and embryos as the water does. And thus, as Prof. F. O. Bower showed in a masterly way many years ago, there began, in increased adaptation to terrestrial life, a series of changes that led to the seed-plants. This came about through a gradual dwindling of the gametophyte and an increasing ascendancy of the sporophyte. To what Hofmeister had described, Bower gave an

evolutionary interpretation. A seed-plant's spores—of two kinds, as in Selaginellas and the like—are the pollen-grains and the embryo-sacs; and the male and female gametophytes are represented by a few nuclear divisions in each, leading to male and female units. It is almost incredible, but it is certain that the sporophyte with its spore-bearing stamens and carpels has practically swallowed the whole of the gametophyte phases; and the seed is a detached megasporangium (or ovule) with an embryo sporophyte enclosed, and with adaptations for nourishment and protection and long lying low. Nature surpassed herself in ingenuity in fashioning the seed.

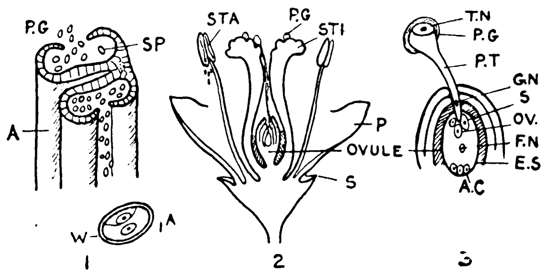


FIG. 150.

Parts of a Flower. A, a cross section through an anther; SP, mother pollen-cells; PG, pollen grains. 1A, a pollen grain with two nuclei, and a firm wall (W). 2, diagram of a flower. S, sepal; P, petal; STA, stamen; PG, pollen grains on the stigma (STI). 3, TN, tube-nucleus; PT, pollen-tube; GN, generative nucleus; S, suspensor cell; OV, ovum or egg-cell; FN, funiculus of the ovule; ES, embryo-sac; AC, antipodal cells.

ORIGIN OF INSECTS.—In many ways insects have been the most successful of animals. On a very moderate estimate there are a quarter of a million different kinds named and known; and the entomologist is still far from an end of his task. In fact, as was said at the famous breakfast-table long ago, it is hardly possible to be an entomologist, the height of reasonable ambition being to become a Coleopterist, or a Dipterologist, or a Hymenopterist, or even a Myrmecologist. Not only are insects successful in the number of their species, they have sinister powers of multiplying, and they form a cloud in the sky which would soon blot out the sun if it were not for the birds and the bad weather. Insects are found everywhere—even out to sea; they eat almost anything—even theological treatises; they make flowers possible, and they are reincarnated in birds; their behaviour is an inexhaustible well of surprises, and some of them have social organisations that make us shudder. But all this is shirking the question: Where did insects come from?

Remembering King Louis' motto, *Divide et impera* (split up your difficulties and you will get the better of them), we divide our problem into sub-problems. This is the only chance of reaching clearness. Our first question is as to the most primitive winged

insects of to-day, and the generally accepted answer is that the simplest forms are to be found in the order Orthoptera, the cockroaches and earwigs, the locusts and grasshoppers. Thus their wings have the simplest patterns, their mouth-parts are the most generalised, and their life-history is not complicated by any true metamorphosis. All zoologists agree that those insects (exopterygotes) in which external wing-buds appear early in the life-history are antecedent to those (endopterygotes) in which hidden wing-buds appear late and lie apparently within the body. The members of the cockroach-locust order are the most primitive living exopterygotes, and represent a type from which it is possible to derive in a tentative way all the other extant orders of winged insects.

Our second question is: What does the rock-record say? And the answer is that the oldest known fossil insects belong to the Upper

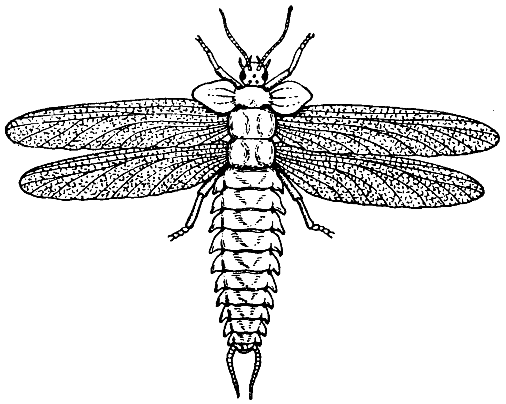


FIG. 151.

One of the Extinct Primitive Insects or Palæodictyoptera. Note a pair of plate-like processes in front of the anterior wings. After Tillyard.

Carboniferous, and that the most primitive of them form an order with a very long name—the Palæodictyoptera. The name may be tedious, but the insects themselves are fascinating in their primitiveness. Thus the rings or segments of the body are all very like one another; the wings stand straight out and do not seem to have been foldable. In front of the wings there are two strange laterally projecting lobes, sometimes with a few veins, extraordinarily like wings in the making. Similarly on each side of the posterior body there is a row of winglike platelets, recalling those seen on the aquatic larvæ of Mayflies. The body always ends in a pair of slender processes, often like the cigar-shaped structures projecting at the tail end of a cockroach. Remarkable in many cases is the large size, for some had a wing-span of 20 inches, which almost justifies the long title Palæodictyoptera!

Now, it is from an extinct order like this that the extant orders of flying insects can be reasonably derived; and in the Carboniferous

Age there emerged primitive cockroaches and their relatives, primitive dragonflies, and primitive Mayflies. As we have already said, it was a time of luxuriant vegetation, with ferns and tree-ferns, horsetails and club-mosses, and true seed-plants related to our conifers and cycads and maidenhair-trees. It was an appropriate environment for insects, and they seem to have made much of it. Yet there were not in the Carboniferous Age any of the higher insects with complete metamorphoses, such as Hymenoptera (ants, bees, and wasps), Diptera (two-winged flies), Coleoptera (beetles), or Lepidoptera (moths and butterflies). But our point is that from the long-named primitive insects of the Upper Carboniferous all the modern orders may be derived, and that without putting any extreme strain on the scientific imagination.

Our third question is: What was the pedigree of the primitive winged insects? And the answer is to be found in the minute Spring-tails and Bristle-tails and their still simpler relatives. Everyone understands that fleas and lice and the like are *secondarily* wingless insects, which have degenerated from winged ancestors; but the little "silver-fish" that run about in the pantry, and the spring-tails that we sometimes see covering the surface of a shore pool, are *primitively* wingless insects. They link the winged insects back to an aboriginal wingless stock, the Protura, minute creatures that live in damp places under stones and bark, or among moss. They are exquisitely simple, and yet they are inseparable from insects. In Eosentomon, which is very widely distributed, there are limbs on the first three rings of the posterior body, and this takes our thoughts back to certain very simple Centipede-like types. The Protura have no antennæ, and in Acerentomon there are no air-tubes or tracheæ. No doubt there may have been some secondary simplification in retrogressive types, but the characters of Protura suggest that insects were evolved from running creatures with posterior as well as anterior legs, and not far removed from the simplest Centipede-types. These again may be linked back to the Ringed Worms or Annelids.

But this brings us to face our last question, the most difficult of all: *How did wings arise?* We look for the answer in the "winglets" of some of the oldest fossil insects, whose name we dare not repeat. Insects' wings always develop as hollow flattened pouches from the upper part of the sides of the body in those rings that bear the two posterior pairs of legs. The "winglets" of some Carboniferous primitive insects grow out on the ring that bears the first pair of legs, and the true wings are as usual. On the posterior body, however, as we have said, there are numerous winglet-like paired outgrowths. As there is no difficulty in assuming the appearance of side pouchings of this sort, the problem narrows itself down to this: What was the original use of these outgrowing flat pockets before they became big

enough, light enough, and mobile enough to serve as wings? An answer—certainly not unreasonable—is that the primitive winglets served as surfaces on which the air-tubes were spread out, thus securing more effective respiration, and also as parachutes for gliding when the Proto-insects were so disposed.

THE ORIGIN OF BIRDS.—The appearance of birds, in Triassic or Jurassic Ages, was one of the great events in animal evolution. Like the rise of insects, it expressed a new emancipation, for typical birds broke the tether that binds most life to earth. And while the Flying Dragons or Pterodactyls, and the Bats, of much later origin, also solved the problem of true flight, the feathered wing stands quite by itself, not comparable with the skin wing of Pterodactyls and Bats, and totally distinct from the chitinous outgrowths of insects.

We take the origin of birds as an illustration of a kind of problem of which we can give only two or three instances—that of the pedigree of a particular type. It may be noted at the outset that the case of bird-pedigree brings out very clearly the strength—and the remaining weakness, too—of the evolutionist way of looking at things. As to the strength, every competent zoologist is convinced that primitive birds emerged millions of years ago from some stock of extinct reptiles. As to the weakness, every careful zoologist will hesitate before committing himself to a statement in regard to the particular group of extinct reptiles from which birds took origin. He will make negative statements to the effect that it could not have been the Pterosaurs, nor the Iguanodons, or their like, that were birds' ancestors. Moreover, if he goes the length of saying, as many have done, that birds sprang from an "Ornithischian" group of bipedal Dinosaurs, he will probably add: "But by what factors the change came about, I know not."

Returning to the first proposition, that birds sprang from a stock of extinct reptiles, it may well be asked why zoologists are so sure of this. For it is a very startling conclusion that the soaring creatures of the air are the scions of a stock that crept or plodded on the earth. No two adjacent classes seem more sharply contrasted than do reptiles and birds.

We quote two paragraphs, expressive of this contrast, from Heilmann's *Origin of Birds* (London, 1926):—

"Every move of the bird is characterised by its warm pulsating blood; its passions are strong, and its feeling so intense as to find expression in song. Its gait is upright; powerful wings lift it without apparent effort into the highest regions of the air; and thence it is able to descend to the earth with the utmost speed, protected by its warm plumage from the greatest variations in temperature; while its vision may be adjusted instantaneously to any distance, thus enabling it, with equal ease, to sight its quarry from afar or near.

"The reptile seems the very opposite to all this. Sluggish and slow it creeps along; it requires sunshine and warmth to stimulate it to action; cold paralyses its every movement. The body is covered with scales, or marled with scutes, and its four limbs are all used in its

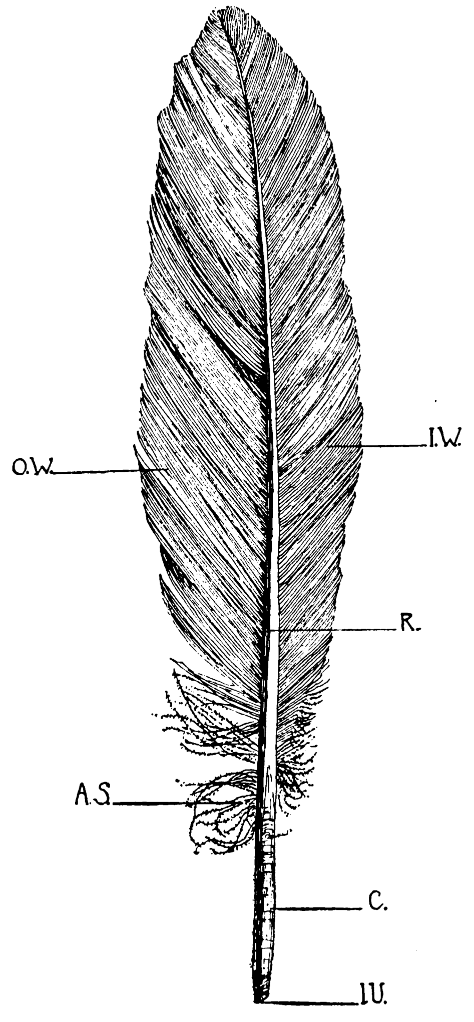


FIG. 152.

Structure of a Typical Feather. From a specimen. IU, inferior umbilicus. where pulp enters; C, calamus or quill; AS, aftershaft; R, rachis or axis of feather; OW, outer half of vane; IW, inner half of vane. The vane consists of numerous barbs united by barbules and barbicels.

progress along the ground. The fore-limb has no resemblance to the bird's wing, and the jaws are usually toothed."

Yet in spite of these deep differences, no competent inquirer, especially since Huxley's clear anatomical comparison and yet co-ordination, doubts that birds sprang from reptiles! Before we consider the reasons for this, it may be of use to point out that the

divergences above indicated are in some measure misleading, for they contrast the modern ends of two sets of branches which have been growing away from one another for millions of years. Secondly, when we think of the ancient reptiles we must not picture a welter of crocodiles and lizards, but a very motley assemblage, among which in Mesozoic Ages there were all sorts of types and tentatives. Some ran on the ground and others swam in the sea; some burrowed and others climbed; some were bipeds, and others were almost snake-like. There were heterogeneous types, testing all things, venturing on all modes of life.

Three lines of evidence converge towards the conclusion that birds evolved from an ancient *saurian* stock—using this general word so as to shift our thoughts away from our particular present-day reptiles. There is evidence (*a*) from homologies of structure, (*b*) from similarities of development, and (*c*) from annectant types.

Deep resemblances in structure and development are termed homologies, and we find that birds and reptiles agree in showing many of these, thus:

(1) a complex lower jaw, made up of 4–6 bones on each side, whereas mammals have but one;
(2) an articulation of this lower jaw with the quadrate bone of the skull, whereas in mammals the articulation is with the squamosal, and the quadrate is reduced to a small ear-bone;
(3) a single occipital condyle at the back of the skull, whereas amphibians and mammals have two;
(4) an inter-tarsal ankle-joint, whereas that of mammals is cruro-tarsal.

This list of agreements might be carried much farther, but that is not necessary for our present purpose. It is of interest, however, to notice an occasional similarity in relatively unimportant details—the straws which show how the evolutionary wind has blown. Thus birds have in the front of their eyeball, at the junction of cornea and sclerotic, a strengthening ring of bone, or of small bones, the sclerotic ring; and this is also evident in many fossil reptiles, such as the Fish-lizards or Ichthyosaurs. Many a bird before and shortly after hatching has a small horny and calcareous "egg-tooth", better called shell-breaker, a hardening at the tip of the upper jaw, which is used in chipping the egg-shell, and is a good instance of an effective structure used for only a few hours or minutes and then discarded. It is of interest that this "shell-breaker" occurs in some reptiles, such as the crocodile, and in that strange living fossil, the New Zealand "lizard" (Sphenodon). It may be noted in passing that this horny shell-breaker is not to be confused with

the true ivory tooth that projects forwards horizontally from the tip of the upper jaw in some lizards and snakes, such as gecko and adder. When there is a true bony "egg-tooth" there is never a horny "shell-breaker", and *vice versa*.

As to *embryonic resemblances* between birds and reptiles, they are manifold. The egg of a goose is externally like that of a crocodile, and the egg of a swan is like one of the smaller Dinosaur eggs which American explorers found in considerable numbers in the Desert of Gobi in Mongolia. Internally also the structure of the egg is the same, with shell-membrane, albumen, and central yolk, and the minute drop of living matter lying like an inverted watch-glass on the top of the yolk—the drop out of which the whole embryo is built up. The mode of ovum-cleavage or segmentation is the same (partial and discoidal), and all the important parts develop in the same fashion. The ante-natal membranes—the protective amnion and the respiratory-nutritive-excretory allantois—are almost exactly the same in reptile and bird. For the first few days the embryo bird and the embryo reptile proceed side by side on the great highway of Amniote development; gradually the paths begin to diverge—when, for instance, the embryo bird shows the first traces of feathers.

In many ways the developing bird within the egg exhibits structures and phases which are recapitulations of what may be found in developing reptiles to-day, or in adult extinct forms in distant ages. The vertebræ may pass through a biconcave stage (recalling those of fishes); the embryo shows, to begin with, only two sacral vertebræ; the ploughshare bone at the tip of the tail is represented by six distinct vertebræ; the breastbone is at first a paired structure; there are seven separate elements in the wrist and two rows at the ankle; the metatarsals are separate in the embryo; there is sometimes an embryonic dental ridge on each jaw, though there are never distinct tooth-germs; Jacobson's organ, a sensory structure on the roof of the mouth below the anterior part of the nasal passage in many reptiles, has been found in some bird embryos, though never in an adult bird. These are but a few instances of the detailed way in which the bird's individual development (ontogeny) condensedly recapitulates the racial evolution (phylogeny), though its advance of a day may represent the slow progress of many thousand years.

As to *annectant types*, several extinct toothed birds are known, such as Hesperornis and Ichthyornis, and many bipedal extinct reptiles. But Hesperornis does not take us very far back from the familiar bird type; thus D'Arcy Thompson points out no fewer than twenty-five skeletal resemblances between it and the Great Northern Diver (Colymbus). In Ichthyornis there are no doubt more lingering traces of the reptile: thus the halves of the lower jaw are quite separate; the enamel-tipped teeth are in sockets, and show successors vertically below them, just as in crocodiles; the vertebræ are bicon-

cave or double-eggcup like, a form characteristic of fishes, rare above that level among living animals, but by no means uncommon among extinct reptiles. According to Marsh, "the brain of Ichthyornis was extraordinarily small, and in its main features strongly reptilian", e.g. in its elongated form and its prominent optic lobes. Its entire bulk he estimated at less than a third of a tern's, while the largest specimen that has been reconstructed must have stood about a foot high. But the fact is that in spite of such well-marked reptilian vestiges, even Ichthyornis does not help us far in our quest. For it was already an indubitable Flying Bird or Carinate, i.e. in the same sub-class as all living birds except the Flightless ostrich tribe Ratitæ.

The oldest known fossil bird, Archæopteryx, is not only of the highest interest in connection with our present problem, but affords one of the clearest illustrations of what is meant by an "annectant type" or "connecting link". So much so that some authorities regard and class it, mistakenly we think, as a reptile, though most others as a bird. The first specimen discovered in 1861 in the lithographic stone quarries at Solenhofen in Bavaria was described by Owen under the name *Archæopteryx lithographica*, and it is one of the treasures of the British Museum. A better preserved specimen, found in 1877 near Eichstatt in Bavaria, was described by Dames and rests in the Berlin Museum. It is sometimes referred to a separate genus, and called *Archæornis siemensi*.

Archæopteryx was a bird about the bulk of a small hen, though of very different build; yet we say "bird" emphatically, because it was a "feathered biped". The marks of the feathers are clearly seen on the fine-grained lithographic stone, and a notable peculiarity is the arrangement of a single row on each side of the long and otherwise lizard-like tail.

Yet the creature swarmed with reptilian features. Thus the skull has *more* resemblance to that of some of the primitive reptiles called Pseudosuchians than to that of modern birds. There are teeth in both jaws, and there is no true "beak", that is to say, no great elongation of the premaxillæ, nor horny covering.

The vertebræ were probably biconcave, as in various extinct reptiles and in most fishes and a few reptiles to-day. There were at least twenty vertebræ in the tail, in striking contrast to the very short tail in all modern birds. For the long "tails" of pheasants and the like are merely feather-tails, their true vertebral tail being reduced and condensed as in ordinary birds. The ribs of Archæopteryx are not bird-like; thus not showing the characteristic hooks or "uncinate processes", which may, however, have been gristly and therefore unpreserved in the fossil. But decidedly reptilian is the presence of 9–12 pairs of ventral or abdominal ribs, interesting structures not even hinted at in any living bird, but very well

developed in the crocodile and Sphenodon, as also in many extinct reptiles. They are interesting structures, developing apart from the main skeleton, as cutaneous ossifications across the ventral wall of the abdomen.

The breastbone is at most vaguely preserved, and the same must be said of the merry-thought. Of the rest of the pectoral girdle it is stated by Petronievicz and Smith Woodward that "although Archæopteryx was obviously a bird of flight, its scapulo-coracoid

FIG. 153.

Bittern, *Botaurus stellaris*. From a specimen. Standing erect among the reeds, with upraised head, the bird well illustrates cryptic coloration. It has a cloak of invisibility.

is more closely similar to that of certain Mesozoic reptiles than that of any other known bird".

The wing of Archæopteryx is in a very interesting phase—intermediate between reptilian and avian fore-limbs. In an ordinary flying bird there is a reduction of digits to the first three, a fusion of half of the wrist or carpal bones with all the three metacarpals to form a firm basis (carpometacarpus) for the longest flight-feathers (the primaries); the free carpal bones are reduced to two, and in most cases there are no claws. In a number of birds there is a claw on the thumb; in rare cases (e.g. ostrich) there is another on the second digit; in the young South American Hoatzin or Opisthocomus

the thumb and the index finger bear claws, which are used in a quaintly reptilian fashion for crawling about on the branches. Now Archæopteryx had three well-developed clawed digits, the metacarpals are free from one another, and there seem to be four distinct carpal bones. There is thus hardly room for doubting that Archæopteryx used its wings in clambering as well as in flight. Different investigators of the two fossils have given different counts (8–12) of the primary feathers, but, whatever the precise number, they were certainly well developed.

As to the hip-girdle, it is more reptilian than avian; thus the number of vertebræ gripped by the ilium is only four, whereas the "syn-sacrum" of modern birds has never fewer than eleven, and sometimes as many as twenty-three. This remarkable increase in numbers is an adaptation to perfected bipedal progression; for so much of the bird's body is in front of a perpendicular dropped from the hip-socket (acetabulum), that there is a great balancing advantage in the long and strong grip that the hip-girdle has taken of the backbone. The toppling-forward tendency, seen in an incipient biped like the Australian Collared Lizard (Chlamydosaurus), and in some very young birds, is corrected by the distribution of the strain over a wide area of backbone. It may be noted that from the width of the pelvis of Archæopteryx it has been possible to calculate the size of the egg, the result being that while Archæopteryx was about the size of the common fowl, its unknown egg could be scarcely a quarter of the size of a hen's. The whole hip-girdle of Archæopteryx is not even half that possessed by an average hen.

As to the hind-leg, it is usually regarded as bird-like, except that the three bones below the ankle-joint (the metatarsals), which are always coalesced in modern birds, appear to have been separate, as they are in reptiles; and Heilmann maintains that there were two free tarsals, while no tarsals remain *as such* in modern birds, the proximal ones fusing to the lower end of the tibia (forming the tibiotarsus), and the distal ones fusing to the upper end of the three coalesced metatarsals (forming the tarso-metatarsus).

Heilmann, whose survey of the facts is the latest, regards Archæopteryx as "a warm-blooded reptile disguised as a bird", and some other zoologists also rule it out of the bird class. This seems to us somewhat perverse, since there is no known hint of feathers in any reptile, and the two words "feathered bipeds" serve as an exclusive definition for the entire class of living birds. We therefore agree with those who regard Archæopteryx as a primitive bird with numerous lingering reptilian features.

Heilmann has redrawn all the bones of Archæopteryx with so much loving care that they have come to life; and his imaginative reconstruction includes even the courtship! He has literally pictured an island in the deep blue Jurassic sea, with giant sea-lizards basking

on the lee-side of the coral reef, and beautifully fluted Ammonite shells sparkling under the tropical sun. A sea-crocodile (Geosaurus) is stranded, and making violent efforts to free itself, churning the water with its tail and paddles. Startled by the splashing, a pair of long-tailed Pterosaurs, with tapering wings like Swifts, skim over the shallow water and then rise high till they are lost like soaring larks. On the beach there are patches of mosses and ferns and club-mosses, but no flowers, not even of grass. Close to the shore there are tree-ferns and Cycads, and farther inland a few araucaria-like Conifers. One misses the modern swarms of insects, though there are a few wasps, clumsy butterflies, and gorgeous dragonflies with a foot-long spread of iridescent wing. Among the club-mosses there are small hairy creatures, somewhat like mice, but with less nimble movements and less intelligent eyes. Some of them have a pouch with two diminutive young ones, for these are primitive Marsupials.

Suddenly a feathered creature (Archæopteryx, of course) launches itself from the top of a tree-fern, and tries ineffectively, half-swooping, half-flying, to catch the glittering dragonfly, much less of a novice in the air. Baulked of its booty, Archæopteryx soars a little and then sinks to the foot of a Cycad-tree. With the help of its strong fore-claws it climbs to the top and rests. It has a grey head, studded with scales, and we are told by this palæontographical Sherlock Holmes that Archæopteryx had coral-red eyes, a black-and-white feathered neck, and for the rest a plain brown plumage! The female, that is to say, for by and by a male comes gliding through the air, reddish in the naked parts of head and neck, with deep steel-coloured general plumage, and an inflatable throat-pouch of scarlet hue. There is a courtship-display and mutual satisfaction. But a second male arrives on the scene, and there is a fierce combat, in the course of which both males fall off the tree and continue their struggle among the ferns. A graceful little creature (a pigmy Dinosaur, called Compsognathus), moving with the swiftness of an arrow, darts through the undergrowth and launches itself on the combatants. In spite of warning cries from the female Archæopteryx on the branches, one of the rival males falls victim to the agile Dinosaur. And here the curtain drops.

We make no apology for borrowing this glimpse of the living Archæopteryx, for though some of the details may be fanciful, Heilmann has shown a sound idea of how the story of the Ascent of Life should—and may—some day be written. In any case there is no doubt that Archæopteryx was a very striking annectant type, linking birds back to saurian ancestors.

BEFORE ARCHÆOPTERYX.—As we have seen, the really difficult question is to find among the numerous stocks of extinct reptiles the most probable ancestry of birds.

The almost universally excluded group is the one that at first sight seems the most probable, namely, that of the Pterosaurs or Pterodactyls. Let us notice briefly why they, though possessed of the power of true flight, cannot be seriously considered. (1) The wing was a skin wing carried out on the enormously elongated fourth finger, and the hand is in other ways entirely different from a bird's. Thus the other digits which reach considerable development in birds are very small in Pterodactyls. (2) The breastbone shows more or less of a keel, and is suggestive of a cormorant's or a gannet's; but against that we must place the development of "abdominal ribs", which are not found in any bird except Archæopteryx. (3) The Pterodactyl bones were pneumatic, like those of birds, but against that we must place the absence of a merry-thought (clavicles united by inter-clavicle). (4) The big orbit, the elongated anterior part of the lightly-built skull, and even the tendency that some Pterodactyls show towards toothlessness, may be used as evidences of avian affinity, but the details of the skull are for the most part different. (5) The weak hind legs are not the least like bird's legs. In short, the claims of the Flying Dragons to be regarded as the ancestors of birds are very weak, indeed unavailing.

On the other hand, there are some good arguments for regarding the Ornithischia—a subdivision of Dinosaurs—as ancestral to birds. The hip-girdle is bird-like; some were bipedal; there is a tendency to a fusion of ankle and instep bones—towards the tarso-metatarsus, which is characteristic of birds.

In his ingenious and scholarly *History of Birds* (1926), Heilmann makes out a good case for another group of extinct reptiles, the Pseudosuchians, which were more primitive than Dinosaurs, and probably their ancestors. In skull, shoulder-girdle, hip-girdle, probable half-erect attitude, some of the Pseudosuchians, such as Ornithosuchus, point towards birds. As Heilmann says: "All our requirements of a bird ancestor are met by the Pseudosuchians, and nothing in their structure militates against the view that one of them might have been the ancestor of the birds."

But while there remains some reasonable doubt as to the details, all zoologists are agreed that birds arose from an ancient reptilian stock,—under what impulses we do not know. To some it seems enough to say that the evolution was accomplished gradually in the course of Natural Selection by the fostering of fit variations and the elimination of the disadvantageous; to others it seems, as W. K. Parker said, that the incipient birds were "*fevered* representatives of reptiles, progressing in the direction of greater and greater constitutional activity". But both these suggestions leave much in the dark, leave us still to "wonder how the slow, cold-blooded, scaly beast ever became transformed into the quick, hot-blooded,

feathered bird, the joy of creation". But we must think not of *transformation*, but of origination and divergence.

EFFECT OF THE ICE-AGES

In the discontent of very severe winters people sometimes say that they are "feeling the cold badly"; and that is the time for a sympathetic consideration of the problem of the Ice Ages. It is only a few thousand years since the great glaciers finally disappeared from Britain, making it possible for man to return to his old haunts, or, in the case of Scotland, to explore new territory. For the first-comers to Scotland, about 10,000 years ago, were, so far as is certain, post-glacial Neolithic hunters and fishers, though there is evidence of Paleolithic forerunners farther south.

Since great ice-sheets, sometimes 3,000 feet thick, had covered the whole of Scotland and most of England during the successive Ice Ages of the Pleistocene Period, the old fauna and flora had been swept away, except such as found refuge along a non-glaciated strip which we call nowadays the South of England. Not only was there an extinction of grandiose creatures like rhinoceros and hippopotamus, mammoth and cave lion; there was a wiping out of practically all the fauna except in ice-free regions, except during the four or so interglacial periods when mild conditions prevailed for cycles of years and allowed adventurous colonists to return for a while.

Some geologists think that we are in an interglacial period even now; and to this the cold ocean depths—now generally interpreted as a survival of the recent ice-age—might readily again contribute, if aided by slight increase of the down currents from Arctic and Antarctic. For we seldom realise how but a few degrees of lowered average annual temperature are needed. But the point is that, after the ice-sheets disappeared and left the land clear, there was a faunistic re-colonisation of Britain from the Continent. For Britain was still just an outlying corner of Europe. Across grassy lowlands, where the North Sea and the English Channel now lie, there came the reindeer and the elk, the bear and the wolf, the lemming and the beaver, besides all the mammals that are still with us. On the heels of these animals, and many of humbler rank, came Neolithic Man, bringing domesticated animals with him. Then a depression of land occurred, Britain became an island, and the door was shut to any further colonisation on the part of terrestrial animals. When we think of the terrible elimination that was effected by the Great Ice Age glaciers—there is no desert like ice!—we can imagine what a faunistically poor country Britain would have been, as regards land animals, if it had been insulated *before* these Ages of Horror,

and had thus been beyond all possibility of re-colonisation, except by creatures that could fly or swim or drift.

We naturally speak of these latest glacial periods as "the *Great Ice Age*", for Europe is still in process of recovering from their inexorable sifting. We know that the changes they brought about were colossal. About two million square miles of Europe and four million square miles of North America were glaciated; indeed, about a fifth of the total land surface of the globe was then ice-covered, though not all at once. Asia and Africa seem to have been but little affected; but we must not forget to include Greenland and Antarctica, where so much ice still remains. But one of the many striking conclusions of modern geology is that before the Great Ice Age there were many Ice Ages, some of them greater than the Great. There are traces of ice-sheets for most of the geological periods, there appear to have been big-scale glaciations during the Huronian, the early Cambrian or late Pre-Cambrian, and the Permo-Carboniferous times—the last-mentioned being the greatest of all. It used to be supposed that the earth was becoming gradually colder down the ages, but the Pre-Cambrian is now regarded as probably the coldest chapter in the earth's history. It used to be a nightmare that our earth would become more and more like an ice-house till all life came to an end; but now the geologists tell us that the inhabitants of a planet that weathered the Permo-Carboniferous Ice Ages need not be too timid about any others, grave though these cannot but be.

All these questions are discussed in a masterly way in Prof. Coleman's *Ice Ages: Recent and Ancient* (1926), and one of the many interesting facts that he emphasises is the irregularity in the occurrence of these catastrophic interruptions of equability. "They seem to be spaced in a haphazard way, and there is no certain evidence of a rhythmic swing, after so many millions of years, from mild to cold and back again." Not a few thoughtful men have advanced theories by means of which the coming and going of Ice Ages have for a time seemed "fully explained". But the problem seems to become more, not less, difficult. For the theory that dominant glaciation is a hint of the gradual refrigeration of the earth is not easily squared with the Pre-Cambrian Ice Ages. The theory that glaciation is the natural consequence of the elevation of parts of the earthcrust above the level of perpetual snow appears an enormous postulate when we think of the vast areas involved at the same time in the two greatest Ice Ages. The occurrence of widespread glaciation has been connected by Wegener and others with the supposed drifting of continents; by others with the supposed wandering of the poles; and by others with supposed great changes in the flow of ocean currents. Shrewd investigators have appealed to changes in the condition, if not the composition, of the atmo-

sphere—in the texture, as it were, of our indispensable blanket. Croll's famous theory referred the Ice Ages to changes in the eccentricity of the earth's orbit, and Sir Robert Ball's venture was on the same line. Again, since sunspots have their rhythm, of some eleven years or thereby, may not the sun have yet larger variations beyond our as yet so brief observation?

What is the theory of the latest authority, Coleman himself? He does not think that any one of the many theories will work; and he has none of his own, beyond a combination of factors. Still, that opens wide fields for further consideration; for any adequate solution of the complicated problems involved must surely come from a conjunction of general and local causes. Some combination of astronomic, geologic, and perhaps even atmospheric conditions seems to be necessary to produce such catastrophic events in the world's history. The rarity of such a conjunction would account for the comparatively few and irregularly spaced times of glaciation which interrupt the usual monotonous continuity of mild conditions shown by palæontology. Whatever the causes of Ice Ages may have been, there is no doubt as to their effects, for they are times of severe sifting, when many fine forms of life are "cast as rubbish to the void". To change the metaphor: an Ice Age prunes the tree of life.

Yet it may also do much more than that—even to favouring the origin and adaptation of new types along its chilly borders. See for conspicuous example the vast abundance and variety of species of grasses, rushes and sedges, and these along our cold temperate region edge, as we approach towards Arctic climate, and we gather many of these as we descend from the moors and by damp brook-banks, to marsh and pool and lakeshore. See how the rushes (Juncaceæ) peculiarly show reduction, both foliar and floral, and each in its own way extreme, from the normal liliaceous type, of which, by common consent of botanists, they are really little if anything more than a sub-order. And though the grasses attain more exuberance and variety, is not this but in abundance of slender leafage, and with reduction of flowers, albeit multitude? And these changes the sedges carry yet further in their own ways. So, too, for the coldward colonising trees, as from various conifers to birches above, and willows and alders below. See, too, the heaths, on drier areas; and the cranberries and the like in moister ones. And, again, after ferns disappear—even to their hardiest, like the deep-rhizomed bracken (Pteris) or the well-coated Ceterach—see how the Lichens, with their extraordinary resistance and persistence, more and more cover the rocks, and even invade the pasture; thus largely overpowering its grasses over vast tundras as from Lapland to North-east Siberia, and onwards from Alaska as well. Do not all these examples, and more, compel us to regard this iceward world-border

as in its own way a notable theatre of plant-evolution? And with this, of course, has to be considered the corresponding fauna, whether vegetarian, as from reindeer to hairy mammoth, or carnivores, so often protected by rich fur. And with these, too, the seal-tribes in the widest sense, so plainly carnivores, which have found their way to ampler food-supplies, and have so well developed their protection against icy waters by not only their twofold coat of fur, but a fat-layer below. So, too, must not even the ancestors of the various whale-tribes have thus by cold and hunger been both urged and tempted out to sea? Again, see how specialised and highly developed are the sea-birds of our coldward northern shores and cliffs—and, in their own way yet more, the amazing penguins of the Antarctic? Does it not seem, then, as if—beyond temperate regions with their comparatively moderate and so far equable conditions, tending early to stabilise their life-forms—the struggle against the polar chills has been favourable to the further variation and adaptation of life?

And is not a further pointer in this direction given by the wide development of migration among so many species of birds—all of which agree in their nesting at the pole-ward limit of their annual range, and never nest, so far as yet known, in the warmer climates of their often much longer sojourn? No doubt the abundance of insect and other food in their northern lands at the spring nesting season must be kept in mind; yet is not this, too, an argument for their life-bracing and even life-developing values? And for early upbringing of young especially; indeed, such as we northerners, when in tropic lands, not only look forward to our return, but positively need to send home our children? So, returning to the migratory birds, may we not at least reasonably suspect their origin in these northern lands, though each in later life be tempted or driven to southward climates for more abundant sustenance in its season? And as for our own species, has it not been in the temperate and cold temperate lands that it has mainly developed its powers and civilisations? May we not even have here the element of truth—though in these times so exaggerated—of the vigour and initiative of northern peoples, and so even to reflect that there may be more value than we have generally seen in Mr. Tilak's thesis of "the Arctic Origin of the Aryans", even if we do not locate them quite so far north?

Notable, too, is the abundance and variety of plankton in the waters of the cold (and even frozen) Arctic and Antarctic seas, in both ways surpassing warmer ones, with its unicellular algæ, radiolarians, etc., with eggs and larvæ of all kinds as well, thus furnishing ample food for its smaller crustaceans, molluscs, etc., which not only in turn feed the fishes, but even the great whales with their vast open mouths for surface-dredge and their whalebone

filter for retaining its contents. Strange, too, to reflect that the many Arctic tragedies of starved explorers, and often of Eskimos as well, need never have taken place; and that Nansen on his long drift with the *Fram* in the ice-pack across the Arctic Ocean was the first guaranteed against failure of normal food-supplies by the simple provision of a few silk plankton-nets, to sink below the ice, and fill with nutritious food from its underlying currents. In all ways, then, have we not increasing evidence for this view of the colder lands and seas as life-encouraging as well as life-selecting? And if so, is not all this a fresh confirmation, from plant and animal life, of the old adage, based mostly on hard individual experience, yet sometimes social experience too—"Sweet are the uses of adversity!"?

VANISHED BRITISH ANIMALS.—Not very long ago, geologically speaking, there was no North Sea, and Britain was an outlier of the Continent. It had then, as we have said, its share of the continental mammals; for there are British remains of the mammoth, the cave-bear, the sabre-toothed tiger, the cave-lion, the woolly rhinoceros, and so on. Gradually, glaciers were formed, and the Ice Ages set in. These were ages of severe sifting, and there were four of them, with three intervening milder spells, during which some of the big animals that had been exterminated in Britain came back again from Southern Europe. But most of Britain, except a strip in the south of England, was thickly covered with ice-sheets, and the result was that almost all the mammals disappeared. Men of some sort were living in North Europe in the later Ice Ages, but remains of the "modern man type", our own *Homo sapiens* species, are all post-glacial.

The second chapter in the story was the amelioration of the climate, the melting of the ice, and the re-colonising of Britain from the Continent. Most of the giants had disappeared from Europe, so they could not be reinstated in Britain; but some stately creatures shared in the re-colonisation, such as the reindeer and the magnificent giant-deer, usually called the "Irish elk". There were also wild cattle and wild boars, wolves and bears, besides some smaller mammals such as beavers and lemming. All these have since been lost; unless we reckon the domestic pig as the descendant of the wild boar. This re-colonisation also included all the diverse wild mammals we now have, though some of these may have lingered in the non-glaciated parts of what is now the south of England.

The third chapter was the shutting of the door. By regional changes in the level of the earth's crust, Great Britain became an island. Ireland also became independent, and its connection with Great Britain was deeply severed before the sister isle had received its full share of the mammals that had been re-established in

England and Scotland. This was one of the earliest injustices to Ireland. Thus there is no evidence that Ireland ever received the mole or the common hare; and her pleasing myth as to the banishment of snakes must, we fear, in time give place to this earlier line of explanation.

The next chapter extends till to-day, and it is from the natural history point of view a sad story of losses. Many mammals that were British at the time of insulation have disappeared entirely, and other kinds are disappearing now. We have entirely lost the reindeer, the giant Irish deer, the bear, the wolf, the beaver, the lemming, and the interesting desman. We are losing the pine-marten, the pole-cat, the wild-cat, and the badger. Apart from bats and seals and cetaceans, there are only twenty-five British mammals to-day.

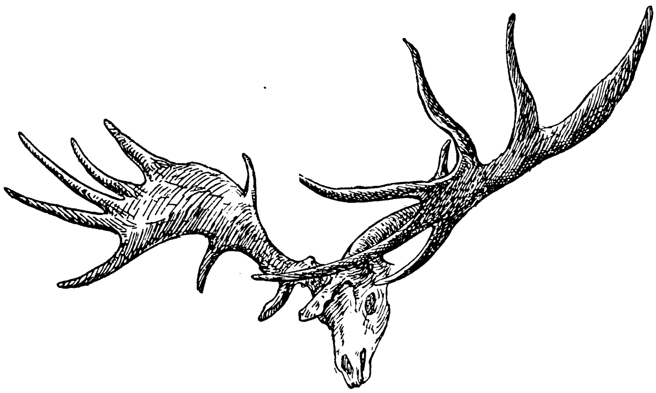


FIG. 154.

Antlers of the Extinct Giant Irish Deer, *Cervus megaceros*. From a specimen. Illustrating exaggerated, perhaps even fatal, sex-hormonised growth. The spread of the antlers may reach to ten feet, and the weight to eighty pounds.

What are the reasons for the disappearance and the dwindling? (1) In a restricted area keen competition may result in extermination. Thus the wolves probably helped in the destruction of the reindeer. (2) It is possible that the amelioration of the climate went too far for some types, which had to leave the milder low grounds and become refugees on the mountains. Thus the Mountain Hare, though very abundant in some parts of the Highlands, has a restricted range to-day compared with what it once had. (3) In the strange case of the giant Irish deer, it seems probable that the creature was its own doom by becoming over-specialised in its antlers. These sometimes had a spread of ten feet and a weight of eighty pounds; and the stags had to grow them afresh each year. It is quite possible for an animal to have too much of a good thing. (4) But the chief cause of disappearance and dwindling was man. He hunted some of the mammals, such as reindeer and wild cattle,

for food and clothing; he hunted others, notably wolves, to secure greater safety for himself and for his flocks.

Even more important was the great reduction of the forests, in which many of the mammals, such as beavers, pine-martens, and red-deer, found shelter. The spread of agriculture and the persistent reduction of wild places must also have made life too hard for some, the shy types especially. We do not blame well-regulated "sport", for that tends on the whole towards preservation. It is probable that the fox would have followed the wolf, if it had not been for fox-hunting.

Another way of looking at the dwindling list of British mammals is to ask how those that are common hold their own. The mole discovered the underworld; the hedgehog is nocturnal, and rolls itself up into an invulnerable ball; the harvest mouse and the shrews are elusively minute; the squirrels store for the hard months; the hare is inconspicuous and full of speed and resource; the stoat lives on its nimble wits; and so one might continue through the list. One must be careful not to include either of the rats as British; for the black rat came about the time of the Crusades and the brown rat early in the eighteenth century. According to some authorities the wild rabbit is another alien, which probably came over with the Conqueror. The fallow-deer was also introduced. Another important point is that the only domesticated mammal that was not introduced from elsewhere is the pig.

It is interesting to inquire into the varied tenacity of the mammals that we have lost. Thus wolves lasted much longer than their associates, the lynx and the brown bear, and were indeed in the sixteenth century so abundant that organised hunting was still enforced by law. The heavy protection of tombs had in part a reference to the ravages of the wolf; and in some places the dead were buried on islands to be out of the reach of the marauders. "He digs the dead from out the sod, and gnaws them under the stars." Some of the remote hospices, or "spittals", like the well-known Spittal of Glenshee, were mainly intended to shelter belated travellers from the prowling wolves.

According to Dr. James Ritchie, who has given a careful account of the matter in his masterly *Animal Life in Scotland* (1920), the last wolf in the north-eastern counties of Scotland was slain in Banffshire in 1644, and the last in Perthshire was killed at Killiecrankie in 1680 by Sir Ewen Cameron of Lochiel. But there are traditions of later dates, especially one that records how in 1743 a wolf, that had killed two children on the hills by the Findhorn, was tracked and destroyed by a Highland hunter, MacQueen by name. It is interesting to notice the number of place-names that tell of the previous presence of wolves, names like Wolfelee, Wolf-gill, and Wolfstan.

There is something to be said for the view that a country is not poorer when it gets rid of its wolves and bears; but this kind of consolation cannot be discovered for such creatures as beavers, pine-martens, and wild cats. The disappointing general fact brought out by Dr. Ritchie's very careful study is the gradual depreciation of the fauna under man's influence. The larger animals disappear, and pigmies take their place; the standard of the fauna sinks. It is true that the actual number of different kinds of animals has not been lessened since Neolithic man settled in Scotland (to take the simpler case) some seven or eight thousand years ago. Fourteen or so species have been banished since man intervened, but we have gained more. Some of these are welcome enough, such as fallow-deer and pheasants; but what compensation for loss is there in gaining rats and insect pests?

As Dr. Ritchie says: "How can the increase of rabbits and sparrows and earthworms and caterpillars and the addition of millions of rats and cockroaches and crickets and bugs ever take the place of those fine creatures round the memories of which the glamour of Scotland's past still plays—the reindeer and the elk, the wolf, the brown bear, the lynx, and the beaver, the bustard, the crane, the bumbling bittern, and many another, lost or disappearing?"

There is undoubtedly an improvement in man's attitude to wild life—a growing desire not to destroy ruthlessly. This is partly due to a diffusion of interest in wild creatures and a greater appreciation of their beauty. It is also due to a clearer recognition of the risks involved in disturbing the balance of Nature. It is now more clearly understood that the destruction of birds and beasts of prey, such as eagles, hawks, owls, pole-cats, stoats, and weasels, is followed by undue increase of small rodents, such as rats and mice and voles.

We are not advocating the restoration of the wolf; but there are some relatively unused parts of the country where there might be reservation parks and sanctuaries to save some of the dwindling animals.

There are many facts that prove the practicability of restoration when that is desirable. Thus the common squirrel, that became extinct in Scotland at the end of the eighteenth century, has been successfully reintroduced. There has been a notable increase in the number of Wild Cats since the War, and the same is true of Golden Eagles.

Another possibility, still in an experimental stage, is the starting of breeding farms for furred animals, such as silver foxes. If man cared more about it, and thought more about it, he could do more not only to control and utilise, but to enrich the animal kingdom of which he is trustee.

LONG-PERSISTENT ANCIENT TYPES.—When Darwin made his explorations in South America on his famous voyage of the *Beagle*—that Columbus voyage in the course of which he discovered a new, that is, an evolving, world—he was greatly impressed by the fact that the living ant-eaters, which are so characteristic of the Neotropical region, had their counterparts in not less characteristic fossil types. This correspondence, between the extinct and the extant, was a seed in the fertile soil of Darwin's mind, and was one of the facts that suggested to him the evolutionist point of view—that the present is the child of the past. It is historically interesting to quote Darwin's words: "This wonderful relationship in the same continent between the dead and the living will, I do not doubt, hereafter throw more light on the appearance of organic beings on our earth, and their disappearance from it, than any other class of facts." Cautious, yet prophetic.

Bagehot, who had an acute mind, once described the evolutionist as one to whom everything is an antiquity. Instead of antiquity we may read Tennyson's fine phrase, "the long result of time". Organic Evolution is occasionally retrogressive, for its immediate directive factor is the sifting of variations that fit, and the conditions demanding fitness may spell degeneracy, as in parasitism; but, on the whole, Organic Evolution is creative, integrative, and progressive. It means testing all things and holding fast that which is good.

At the time of the *Beagle* voyage, Darwin did not know of another South American type, the double-breathing mudfish, Lepidosiren, which frequents the marshes of the Amazon and its affluents, and lies low in its mud-burrow during the dry season. But later on, in *The Origin of Species*, we find the great naturalist using the now familiar title, "living fossils", and referring to Lepidosiren as one of the persistent anomalous types which "connect to a certain extent orders at present widely sundered in the natural scale". For the sluggish Lepidosiren, which Graham Kerr has studied to such good purpose, links modern fishes back to types of Old Red Sandstone or even earlier origin, and points forwards in its lung-breathing to the Amphibians. Along with Ceratodus of Queensland and Protopterus of Africa, this quaint "Lolach", as the natives call it, is a modern survivor of an ancient race. It is a "living fossil".

Another modern fish that is hoary with antiquity is the Polypterus of the Nile and other African rivers. Along with the agile Calamoichthys of Calabar, it represents to-day the great antique order of Fringe-finned fishes or Crossopterygians, which began in the Old Red Sandstone period or earlier, and gave rise to the Bony Fishes and the Mudfishes, perhaps to Amphibians themselves. We are not saying that there are fossil forms of Polypterus or its only surviving

relative, for we believe that none is yet known; the point is that Polypterus and Calamoichthys are the sole survivors to-day of the Crossopterygians of the Old Red Sandstone that roused Hugh Miller's enthusiasm many years ago.

What veneration we have for an old picture painted a few hundred years ago, for an old stone weapon fashioned a few thousand years ago, for a Piltdown skull grown a few hundreds of thousands of years ago, for the fossil remains of the first-known bird (Archæopteryx) entombed a few millions of years ago! Yet what modernities these are compared with types that emerged in Silurian or even Devonian ages. An eminent authority writes: "No geologist to-day thinks that the evolution of the earth and its life could have taken place in less than 100 million years. My own view, as a student of Historical Geology, is that geologic time endured about 800 million years." It is dramatic to add the date of this conclusion of Prof. Schuchert's: it is 1918, so we see Anno Domini against a stupendous background of ages! And however much we may distrust geological estimates of age—if we are competent to distrust them—we must keep in mind that—if we sum up, as geologists sometimes do, all the subsequent strata as if superposed and undenuded, and so surviving—then, before we could dig back to the most recent Palæozoic rocks—that is, to the ages of fish dominance—we should have to get through some twenty miles of sedimentary rocks, the making of which means some time. And then to get back to the beginning of the Palæozoic rocks—that is, to the ages when backboneless animals, like Trilobites, crowned creation—we should have to get through another thirty miles of sandstones, mudstones, and limestones.

Everything is an antiquity; and we can, if we like, trace our long pedigree back to the primitive Protists of the primeval sea. But the humanoid race did not emerge, separating itself, so to speak, from the anthropoid, till, say, between one and two million years ago. "Microcosms," Plato called us, because we incorporate all creation—a profoundly true idea—but while our being includes strands that were first spun unnumbered millions of years ago, the weaving of the web that began to approach Man was an achievement less unthinkably remote. It has been pointed out that if one could arrange a great cinema-film of Organic Evolution, giving proportionate time to the successive geological periods, with their characteristic steps of progress—such as fish to frog, and reptile to mammal—and if we began the solemn march of events about one o'clock in the afternoon, allowing ten million years to the hour, it would require a good deal of speeding up to get to the advent of man by closing-time, say at about five minutes before midnight. (Some would say one minute, but we need not thus quarrel over millions!) Our point, however, is to make a distinction between the

emergence of a definite race, and the origin of particular strands, such as a backbone, which goes back to an early palæozoic initiative of life.

Some of the living fossils are fascinatingly curious. There is the New Zealand lizard (Sphenodon or Hatteria), for instance, the sole survivor of an ancient race of primitive reptiles. "Lizard", it is called, but that is merely for courtesy or convenience; it is the sole survivor of the ancient Cretaceous and once flourishing order of Reptiles called Rhynchocephalia. It is a quaint living fossil—sharing its burrow with a petrel, though that is neither here nor there; it is anatomically an antediluvian, a Rip van Winkle, a survival, a living fossil. Its pineal body testifies to its antiquity, for it bears a third upward-looking eye!

Another of these venerable types is very familiar to zoologists, but little known to the laity. It is commonly referred to as Peripatus, though the specialists distinguish various genera—Peripatoides, Peripatopsis, Paraperipatus, and so on: and it has an extraordinarily wide representation in many parts of the world, such as tropical America, Chili, Thibet, South Africa, Australia, and Malaya. The meaning of this wide distribution is plainly that this caterpillar-looking creature is of very ancient origin, and has had time to colonise most countries. It lives a cryptozoic life, shy and nocturnal, hiding under bark and leaves, feeding on small insects, which it catches in a quite unique way by squirting jets of slime from its mouth. It moves quickly, something like a millipede, and coils up in a flat circle when irritated. Here, if anywhere, is an archaic creature, a survivor of the ancient types of air-breathing animals that advanced from an Annelid worm stock towards the Tracheates, like Centipedes and Insects. It is sometimes described as having the kidney-tubes of an earthworm and the air-tubes of an insect, two structures never again found together in one animal. Another peculiarity is that the mother Peripatus may bear the young ones about before birth for longer than a mare carries her foal. No fossil forms are known; indeed, such a soft-skinned land-creature would not often be preserved; and yet in Darwin's sense it is fair to speak of Peripatus as a living fossil. And there is another interesting aspect to which its first embryologist, the late Prof. Sedgwick, alluded enthusiastically: "The exquisite sensitiveness and continually changing form of the antennæ, the well-rounded plump body, the eyes set like small diamonds on the side of the head, the delicate feet, and, above all, the rich colouring and velvety texture of the skin, all combine to give these animals an aspect of quite exceptional beauty." Thus a living fossil may also be a living jewel. Many other examples might be given— difficult facts for the fundamentalists; but we must be content with these instances of the way in which the past often lives on in the present, the old amid the new.

ANACHRONISMS.—It is fundamentally characteristic of living creatures that their past lives in their present. This is familiarly illustrated at various levels, rising on the psychological side to true memory in the individual lifetime; but it is equally true of the organic racial past, that it lives again in the individual. In some way that we cannot picture, the germ-cell is a repertory of experiments in organisation that were taken by ancestral germ-cells, and confirmed in the lifetime of individual ancestors. Enregistration of the past is characteristic of life. Only in a very restricted way does the past live on in the present of lifeless things. They say that a bar of iron is never quite the same after it has been severely jarred, and there is much inquiry nowadays into the "fatigue" of metals. We have even read of an oil that showed traces of "memory"; but this must surely have been a freak. Personally, we do not know enough to follow this line of thought, yet there are musicians who would never dream of lending their violin to a mediocre player; and it is quite possible that a really subtle instrument responds in some way not readily statable to the usage it gets from a fine fiddler.

It is a good rule of sound thinking not to try to make different things seem the same; and therefore we feel that there is apt to be a fallacy, or at least an exaggeration, in using such metaphors as the "fatigue" of metals and a violin's "memory". Yet there is no doubt that in the inorganic domain there are adumbrations of what is characteristic of living creatures, the power of enregistering experience so that it influences subsequent behaviour. The universe has continuity. But it is only in living creatures that we can speak with firmness of the past living on in the present—enduring in the sense of Bergson's untranslatable "durée"—not duration, but enduration, and more.

But great advantages often involve a tax, and the tax on the enregistration of the past is the risk of retaining what become anachronisms. For this law is even-handed; along with much that is invaluable there may be a hereditary entailment of some item or feature that has outlived its utility, and may even have become a handicap. Yet this last is far too much to say of most of the vestigial organs which are of common occurrence in animals; most of them are neither here nor there; they are not even expensive to keep up; they are negligible survivals, like the unsounded letters in many words, like the "o" in leopard or the "b" in doubt. The whale is not burdened by its deeply buried vestigial hip-girdle and hind-legs, and there is no reason to believe that the unborn whalebone whale is put about by the persistence of two sets of vestigial teeth which never cut the gums. Relics of the past are apt to vary in a curious way, and they may become seats of disease, partly because they are out of the current of healthfulness; but in most

cases they are practically unimportant—just straws showing how the evolution-wind has blown.

In man there are many of these more or less anachronistic structures; in fact, it is forty years since that excellent anatomist Wiedersheim reckoned up 126 or thereby. Thus it is often stated by those who ought to know that man would be a healthier creature if he had no vermiform appendix. He certainly seems to get on very well without it. It is often stated—we like to be cautious about these matters—that man's food-canal, about thirty feet, is far too long. It was adapted for days when the food was coarse and poor, and when the meals were very unpunctual—when, in short, man had to eat large quantities. Especially is the length of the large

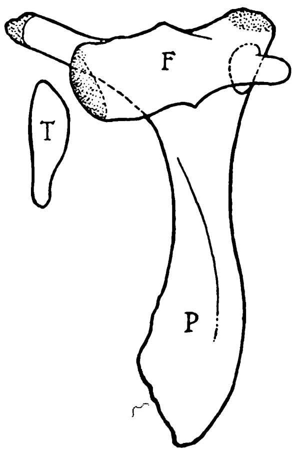


FIG. 155.

Vestigial Hip-Girdle and Hind-Limb of a Whale. After Struthers. P, vestige of pelvis; F, vestige of femur; T, vestige of tibia.

intestine regarded as an anachronism in these days of condensed, highly nutritious food and regular meals.

Then there are the wisdom teeth or third molars, which are often late of appearing and of little use. They are often more trouble than they are worth. They are part of our complement of thirty-two teeth, inherited from prehuman ancestors, which have become overcrowded in man owing to the obvious shortening down of the region of the mammalian snout. It may be, however, that it is hypercritical to speak of our wisdom teeth as anachronisms; for if they have anything to do with wisdom we never needed them more.

Another kind of anachronism has to do with function. It occasionally happens that an old-fashioned way of doing something persists as an aberration. This usually spells disease, for instance in the excretory system; and it finds few illustrations except in man.

It must be distinguished from imperfections that result from arrest of development, such as hare-lip, or a slight lack of finish in the heart. It would be interesting to inquire whether the imperfect warm-bloodedness of some mammals, notably the hibernators, was an arrest of development, for the newborn mammal is often, though not always, comparatively cold-blooded; or whether it was sometimes a persistent reptilian anachronism. The second interpretation is suggested in the case of the two old-fashioned egg-laying mammals, the duckmole and the spiny ant-eater (Ornithorhyncus and Echidna), both very imperfectly warm-blooded.

Anachronisms are familiar in domesticated animals, as in the "shying" horse, or in the dog that turns round and round in the imaginary herbage of the hearthrug. Some of the ways of children, that are often misunderstood, are just anachronisms; as may be illustrated by the reassertion of desires for a primitive dietary. Prof. M. S. Pembrey writes in a recent collective work, *Evolution in the Light of Modern Knowledge* (Blackie, Glasgow, 1925): "The child shows that he retains some of the primitive instincts which are a guide to life; he has a great liking for raw fruit, nuts, turnips, and swedes, which are regarded by his elders as indigestible. These raw foods have been recognised recently as rich in constituents especially valuable for healthy growth. The petty pilfering of orchards by children should be regarded as a sign, not of original sin, but of an instinctive desire for vitamins."

It is not in children only that anachronisms persist, for there are survivals of old types among those who have reached years of great discretion. Tennyson speaks of the ape and tiger within us, and Walt Whitman confessed that he was stuccoed all over with quadrupeds. The robber baron is with us still, in "all the ranks of society"; and the patriarchate survives in many a household. No one who has not been a-shootin' or a-fishin' can regard poaching as a serious moral offence; it is only an anachronism. But we are afraid to pursue this line of thought. It should be noted, however, that it is bad biology to think of these ancient strands in our personality as persisting in their primeval simioid or tigroid or neanderthaloid texture. The organism is a unity and is always making itself a unity afresh; the ancient strands, though often so liable to knot, have all been in some measure humanised.

No doubt there are anachronistic occupations and professions. The "worm-eaters" who make new furniture look old, must surely be anachronisms, if the word means anything; and the quack is an anachronism in these days when there are so many good doctors unemployed. Even lecturing is in no small degree an anachronism, in its too frequent attempt to ignore the invention of printing. In his work on the *Ancien Régime,* Taine gives a list of honorary or supernumerary posts at the Court of Versailles, such as the Steward

of the Royal Hunt, who had no duties save signing his name twice a year. It would be an anachronism to suppose that there are no anachronisms in our midst to-day.

It would be of high value to make an *index expurgatorius* of anachronistic forms of speech, that confuse issues and dull clear thinking. We mean mischievous anachronisms, such as the withering retort when an uncomfortable puncturing fact is adduced—"Oh, but that's the exception that proves the rule." But even worse than forms of speech that have drifted from their old moorings are anachronisms of thought and action. Thus indiscriminate alms-giving and dysgenic parentage are anachronisms of conduct; and anti-evolutionist argument is an anachronism of thought. But saddest of all in personal experience is the first glimpse one gets of the fact that one has oneself become an anachronism!

RETROSPECT: THE CHANGING WORLD-ENVIRONMENT.—In our short human lifetimes, and even within the history of our after all very recent science, the world-environment of life seems broadly stable. But with that longer view of the cosmic past, and of its varied scenes of life, which geology and palæontology have given us, we cannot too clearly keep before our minds the vast changes of the environment of life which have been and still are in progress. Notably, for instance, those of the composition of the atmosphere since earliest times. Thus note first the perpetual reduction of the carbon dioxide of the atmosphere, and this not simply by plant life as preserved in coal, etc., but also by the vast accumulation in many strata of the hard parts of animals. Note again the corresponding increase of the oxygen of the atmosphere, for, as Kelvin pointed out many years ago, the bulk of the oxygen of the atmosphere must have been substantially fixed through the oxidation of the earth's crust before and during its consolidation, so that the present high proportion of 21 per cent. must have substantially accumulated from the photosynthetic activity of green plants throughout their history. But if these two processes of atmospheric change be admitted as in progress throughout evolutionary history, must not our general retrospect of evolution in its physiological terms give a very considerable importance to this increase of oxygen, with its ever-intensifying respiratory stimulus to the activities of life? And correspondingly, in the decrease of CO_2, must we not see a concurrent factor towards their activation also? That for the Carboniferous flora the atmosphere must have been substantially richer in CO_2 than now, has often been pointed out as a condition favourable to its exuberance: and conversely, throughout this ever-continuing impoverishment of the atmosphere for vegetation, we cannot but recognise the advantage of all manner of variations favourable to photosynthetic efficiency, in which the

plant-world has been so rich, and its types are so successfully adaptive.

Again, in that advancing desiccation of our planet, with increase of dryness even towards desertic conditions over vast areas, we have another potent cosmic factor of evolution, and with a new variety of plant adaptations accordingly. Conversely, too, the development of plants along the range of inland water-margins and of marshes, shows also no lack of appropriate adaptations, as of course also many related to the enrichment and deepening of soils from the decomposition of vegetable growth. Again, experiments have shown varied response and change in embryonic forms, from slight changes in the composition of their surrounding water: and thus we can well imagine that the increasing salinity of the ocean has been a notable factor in the appearance of variations, as well as in the selection of the fittest.

Between these cumulative changes of environment throughout evolutionary time on the one hand, and on the other the annual changes of the seasons, also so frequently with characteristic life-adaptations, we have also to realise the enormous range of intermediate changes, as from the recurrence of glacial periods to the wide range of geologic alterations of the earth's surfaces and levels, and from slow but extensive geologic and geographic changes to sudden catastrophes. So, as the geologic world-phantasmagoria becomes more and more vividly and comprehensively presented to the mind, it is no wonder that palæontologists and geographers so frequently attach great or even predominant importance to such large environmental changes as significant to the appearance as well as the selection of variations in the forms of life; and that they are little moved by arguments against their views even when supported by experiments, since these are necessarily on a scale of magnitude and time infinitesimal in proportion to those of their studies.

RECURRENT GLACIAL PERIODS AS EVOLUTIONARY FACTORS.—Though Ramsay and others were teaching this recurrence fifty years ago, two recent and notable books of complemental viewpoint, geological and climatological respectively, yet in broad agreement, greatly clear up the subject, as has been pointed out in able exposition by Dr. Newbigin. First, by their agreement on at least three major Ice Ages—Huronian, Cambrian, and Permo-Carboniferous—before the recent and best studied Pleistocene one, from whose chilling grasp the world is not yet free. Next, in abandoning Croll's and other astronomical theories, and returning to geologic and geographic ones—of great tectonic uplifts, with differences of relief and of distribution of land and water.

Furthermore, coming to what here mainly concerns us, they lay great stress on the bearing of these great periods of cold climate—and indeed also of minor ones, especially that of the early Eocene—upon the progression of organic life. Says our first author, Prof. Coleman of Toronto: "The process of elimination of the weaker, less adaptable, forms during Ice Ages seems one of the most effective ways in which new and more viable species arise; so that the ever-multiplying plants and animals have their ranks thinned, leaving room for the more progressive species. The hastening and intensifying of the process of evolution in glacial periods is undoubtedly one of the most important ways of developing the life of the world, and should receive the special attention of biologists."

In his *Climate through the Ages* (1926), Mr. C. Brooks compares Ice Ages in the climatic history of our planet to cyclones in a tropical island. As hitherto, but now more fully, he reasonably assumes the character and past distribution of characteristic vegetation as indicative of prevalent climates at given places and times; so from many facts, like the existence of *Sequoia gigantea* ("Wellingtonia") in Tertiary Greenland, we see that the mean sea-level temperature must have been everywhere higher than at present; whence warmer tropics, sub-tropical climate in our temperate zone, temperate polar areas, and practically no polar climate as at present. In these long "periods of normal climate", the rains in what are now temperate regions would thus be less frequent, but of sub-tropical character, with rapid evaporation and dry periods between. His conception is of long normal periods, modified by abnormal yet cyclically recurrent glacial periods; and it thus suggestively combines, upon our modern spiral, the values of uniformitarian geology with those of more catastrophic views. And if such alternations in the genesis of our physical world are cyclic, and thus fall into the rhythm of one great metastrophe, may not our difficulties in the general understanding of organic evolution be abated by again thinking of its changes as associatedly metastrophic? For thus we can better understand the stabilities and permanences of life's history, yet also its striking disappearances; its innovations also; and these from "big lifts" to manifold differentiation of species in detail—all becoming more intelligible. Such ideas have indeed been long coming up, in fact, since the oldest doctrines of "creative periods", yet it is much if we are thus reaching a clearer general conception of the world process, and this with increasing light upon its particulars.

Dr. Newbigin ably condenses and sometimes develops the conceptions of both our authors, reviewing the main ascents of life and the increase of diversity of type and species, in association with these cyclic changes of world configuration and climate. The development of diversity of type seems associated with an increase in the area occupied by terrestrial organisms. Thus in warm conditions

reptiles and primitive Gymnosperms were widely distributed, but with the early Eocene cold the larger forms died out. Rapid evolution took place where small forms could resist, whence modern mammals and angiosperms. With the return of warmer conditions would come their widening colonisation, and their fuller adaptation also, even to desertic regions and their extreme climates. Such progress in evolution under the influence of Ice Ages thus needed increasing adaptability to physical conditions; thin-skinned amphibians thus giving place to scaly reptiles, and these to feathered birds and hairy mammals, with their high blood temperatures. Finally came man, with his practically universal distribution, since beyond such organic advances he has used his intelligence. The rise of modern man in the Northern Hemisphere, most influenced by the last Ice Age, is here significant; and this notably in association with its favouring the growth of grassland in place of the Tertiary forests. Thus even man's civilised and modern development of pastoral and cereal agriculture may be viewed as his continuation of nature's process; and this ever since it may well have been one of the early Ice Ages which led to the emergence and evolution of the first land plants and animals.

In such colossal world-changes we may also profitably reflect upon the evolution-processes, generally more separately and specially considered. Thus for the Darwinian schools, what more dramatic and comprehensive forces of natural elimination, leading to natural selection, with survival of the more adaptive forms, than at the stages so critical for life of these great climatic rhythms? Yet also the schools of Lamarckian descent must say, amid such cosmic stress—what organic strain to meet it—what internal need and organic urge towards readjustment—what *élan vital*—what surpassing of mneme by horme! And so above all in man—and with what intensive arousal of intelligence by difficulties; and towards readaptations of every realisable kind, up to social grouping, towards better resistance to hard environment and even increasing domination of it.

Hence, too, great influences towards favouring the evolution of sex in higher animals, to its increasing individuation; and also to the advances of mothering and parental care. And this not only as culminant for the reproductive life, but also as reacting on the individual and self-maintaining organisation as well, and in various measure. Hence, indeed, our insistence upon divergent lines of evolution, and these from varieties and species to larger and larger groups, broadly contrasted as predominantly anabolic and katabolic, more passive and more active; and thus ranging from feminoid and masculoid species (like bee and wasp, etc.) to the very origins of plants and animals themselves. (See Section on Reproduction and Sex.)

In plant evolution there seems especially manifested the repression of reproductive development and maturity by the cold of the Ice Ages, with encouragement to the vegetative life by the ample moisture available below the margin of snow and ice, so that the vast development and differentiation of the grassy, sedgy, and rushy types, from simpler and more flowery liliaceous ancestry, becomes more intelligible. And that this is no mere speculative gaze into the glacial past is manifest in every alpine area, as so notably in the Swiss meadow; for though so bright and varied in its spaces of flower-favouring sunshine, the grassy types are still predominant; and in its shady nooks the surviving orchid flowers are often green; in striking contrast with their sun-loving kindred and neighbours.

Recall, too, as at once favoured and urged by hard conditions, that mothering of offspring, even within the parental body, which is so much older, deeper, and more general in the plant world than in the animal: witness the flower with its long-hidden secret, its protection of the reproductive generation by the more vegetative and asexual one (Chapter VII). In all manner of ways, then, the significance of palæontology for evolution, of past for present, becomes increasingly encouraging to continued inquiry.

PALÆONTOGRAPHY AND PRESENT DISTRIBUTION.—The term "palæontography" for our "ancient-beings-lore" helps to express the scientific resurrection of life throughout its past, since for the true palæontologist—as distinguished from mere collector—his plant and animal fossils live anew, and in the very environment of their lives. Past landscapes and seas thus reappear, wellnigh as plain before his inward eye as those which to-day surround him. Moreover, fossil forms are increasingly revealing their various lines of evolution, and thus illuminating those continued by our modern species, as from horses or elephants to molluscs, or again from ferny forests to that floral exuberance of nature of which our greatest gardens are but a scanty gathering.

Yet as the student of history is apt to remain in his chosen period and leave the historic interest of his own times to the everyday newspaper mind, so the palæontographer and the field-naturalist too seldom bring these interests together into their real and vital continuity. The geographical distribution of plants and animals thus remains, to most students and to many writers, a practically separated sub-science of Biology: whereas its descriptions are of the current scene of the life-drama, that which in its turn is occupying the world-stage. Yet every geologist, geographer, and taxonomist knows this, and as no mere general statement. Their attempt is to realise, to trace and visualise, with ever-increasing concreteness, each of the long succession of past ages which

have preceded and prepared the present. And next they see this present world and its forms of life as but in their turn dominant, yet already partly fading into the past, as its rarer species disappear. Yet also so far preparing the future, as its commoner forms spread and vary.

The animal palæontologist has not a few living fossils, but more conspicuous are the long-surviving species of the plant world. Various Cycads and ferns give conspicuous examples of this, but perhaps plainest of all are the survivals of the Tertiary flora upon the vast heath-formations or upon their margins, over the Mediterranean uplands, such as *Pistacia lentiscus*, and often also exuberant in cultivation; witness walnut, pomegranate, oleander, Judas-tree, laurel, and that commonest and hardiest of palms, *Chamærops humilis*. Most curious is the survival of *Gingko biloba*, now familiar beyond botanic gardens, but imported from Japanese temple-gardens, and not yet found in nature.

Palæontology has thus got far beyond that simple searching and gathering, listing and classing of fossils as curious natural antiquities, which is all that some still see in it. From this indispensable material —fragmentary and broken though it so largely is, and still after a century and more of increasing quest a woefully imperfect record, and one we see no hope of completing as we would desire, since practically only organisms with hard parts could bequeath us any record of their existence—the past of life, even to our own, has now to no small extent arisen from the dead. And this so surely, so vividly, that we can now call in the painter, the modeller, or sculptor to our aid, so that the great museums of palæontology, especially in America, yet increasingly in other countries as well, are already becoming wonder-houses second to none. Yet even these are but sketches and studies towards the museums of the future, with their panoramic halls for the successive phases of the past, with their long-vanished world-landscapes renewed, and each with the vegetation and animal life characteristic of its time. Nor will all this be a "mere popularisation" of science, but its freshening aid and stimulus. For each such scene, incomplete as it still must be, must stimulate more than ever the questions of all the sciences concerned. Thus, how did this distinctive geologic scene come about? How did it become peopled with these leading actors, so largely new? And how did these in their turn so largely disappear? And was this with or without some new type of offspring in their turn? All these questions and more will be increasingly obvious and insistent; so recruiting by fresh youth the ever-thinning ranks of geologists and palæontologists, of botanists and zoologists, at once evolutionists and physiologists, and sending these out as inquirers anew. In 1926 the exploring expeditions, naturalistic and humanistic together, were reckoned as many as two hundred; and even at an

increasing rate it will be long before our museums are as complete as may be, and longer still before the questions they arouse are adequately answered.

The greater discoveries in European palæontology were mainly before the epoch-making Darwinian movement, and though distinguished work has of course continued to be done, and by many investigators, of whom we may take Kowalewsky as an outstanding example, the most striking harvests of new forms, mammalian and reptilian especially, have been those rewarding North American workers after that date, as so notably in the last generation: witness Cope, Marsh, Leidy, etc., and now more recently Osborn, Lull, and others. From Lull's masterly outline of *Organic Evolution* we may here cite a passage, from his epilogue, entitled "The Pulse of Life", since asking one or two of such main questions as are above indicated, and with broadly outlined answers; and these also of interest as characteristic of the large way in which palæontologists are nowadays thinking:

"The stream of life flows so slowly that the imagination fails to grasp the immensity of time required for its passage, but like many another stream it pulses irregularly as it flows. There are times of quickening, the expression points of evolution, which are almost invariably coincident with some great geological change, and the correspondence is so exact and so frequent that the laws of chance must not be invoked by way of explanation. The geologic changes and the pulse of life stand to each other in the relation of cause and effect. This statement does not, however, imply the acceptance of the Lamarckian factor any more than that of natural selection, for whether the influence of a changing environment acts directly upon the creature's body, or indirectly through induced habit, or whether it merely sets a standard to which animals must conform if they would survive, matters not; the fundamental principle remains that changing environmental conditions stimulate the sluggish evolution stream to quickened movement" (Lull's *Organic Evolution*, 1917, p. 687).

This is well said, and the author has been notably successful in correlating the pulse of life with influences of climate, chiefly temperature and moisture variation, due to topographic or to general atmospheric conditions. "Back of these climatic changes lies, as one of the great fundamental causes, earth shrinkage, with a consequent warping of the crust which produces mountain ranges and enlarges the lands. Thus it will be seen that the most momentous changes, so far as influence on life is concerned, may have, geologically speaking, a very simple basic cause." Yet in thinking of the external causes that influence the course of evolution, we must not forget that we started with "the stream of life".

CAN THERE BE LIFE BEYOND OUR WORLD LIMITS?— This old question is one too persistently recurrent to be ignored. At present we have no positive assurance of the existence even of water—so indispensable to life as we know it—upon any other planet, save probably or possibly Mars, and no great faith in "red vegetation" or anything very similar to our forms of plant-life, let alone animal or human life. Moreover, all that astronomers have yet discerned of other planets makes it impossible to form any conception of life upon them at all comparable to ours, while of planets around other suns we have as yet no evidence at all. Hence it is not to be wondered at that so reflective and open-minded a biologist as Alfred Russel Wallace, in no small measure nearest to Darwin's own magnitude and main achievement, should practically have returned to the ancient cosmogony, with its view of the uniqueness of this world of ours, so far as organic life and humanity are concerned. Yet none the less this speculative dream indestructibly persists, or returns, of something in principle comparable to life, as we know it, having also its place and time within this Universe of Universes, of still but faintly measured vastness, and unknown potentialities. For with such practical infinitude of environment, yet this fundamentally akin in chemical composition and energic processes, and with limitless time, as well as space, for evolution-processes without number, how can we think of our terrestrial life-manifestation as absolutely and permanently unique? Returning, however, to our own earth's companion planets, even though for the presence of life Jupiter be as yet too warm, must he not be cooling down, more or less as the earth has done? And as for even the farther away planets, with what for earth-life would be too scanty light and heat, who can say but that they may—or may yet—have their success in bearing modes and forms of life comparable to that of more fully economic green plants, i.e. economic in the above sense, for chlorophyllian plants, than are ours? Or may nearer planets be or become in some way better veiled, or with life-mode less economic of what for our life-forms would be excessive light and heat?

After all, our terrestrial and organic Life as we know it needs our very definite physical conditions for its existence, and these are not elsewhere discovered. So what more can be said? What field, even for speculation, remains, save that in so far as other planets, in course of astronomic and geologic time, may conceivably more or less arrive at such viable conditions also?

Yet at least one other field remains open to speculation. Recall how though our visible spectrum is but of a single octave among the sixty-two we now recognise, and can even so far create and control, we also know that other forms of organic life can visually appreciate rays of wave-lengths beyond ours on either hand; and similarly for

those vibrations to us recognisable as heat and sound. Moreover, what we can only sense as light, and which we cannot organically emit, other organisms, e.g. fire-flies, can and do produce. And what to animals seems but visual light is to the green plant photosynthetic; and even the inorganic magnet has emissive powers in its own electromagnetic way, yet this so far controllable by our intelligence. The discoveries, interpretations, and powers of physical research—as with "wireless", with radio-activity, even to transmutation, and with strange properties of other elements, as from those of selenium to the muscle-like responses of tin, etc., to stimulants and depressants long ago demonstrated by Bose, may reasonably be viewed, not as ending, but rather only beginning; while the current analyses of atomic composition and their disclosure of vast new ranges of energies is ever extending, and also opening the field to new synthetic speculations, such as Rutot's. Yet how can all this physicochemical progress be in any way related to Life, as we know it?

Notice, however, that the most general of biological conceptions—that of integration of some definite continuity of form and function in interaction with environment, briefly (Efo/Ofe), is not necessarily limited to our particular terrestrial conditions; but is so far not wholly inconceivable elsewhere and in other conditions also. In like measure neither can we exclude from these the conception of something of psychologic meaning and significance in association with such embodiment and process. But if so, the fields of the Universe open to Life within this most general conception of it may be indeed super-protean. Yet that the advance of science may or may not disclose something of this, who can tell?

The more we ourselves already so much sense the Universe, and so far begin to understand it, the less can we imagine our particular senses to be the only vehicles of such recipience. A greater speculation was surely Newton's: "It may be that the infinite ether is the sensorium of God!" Such theologic speculation is beyond us; yet the ancient initiative of theologies and their cosmogonies has ever been renewing on the scientific level—from the older astronomers so frequently thinking of "The Plurality of Worlds", and again since the Nebular Hypothesis of Kant and Laplace onwards, even up to discussion, albeit unfavourable, in such a work as Jeans' *Cosmogony* to-day. There are enough of eagerly speculative students of biology to form a "Société Bio-Cosmique", with its "Revue"—the papers published in this ranging from "plasmology" outwards into the Universe. The keen and subtly speculative reasonings of Rutot and other workers, upon the data of contemporary physical science, are still more difficult to ignore.

Thus the human mind is ever and anon renewing such cosmic and biocosmic speculation; and when we recall the marvellous

progress of spectroscopy beyond even telescopy, no one can set limits to further extensions even of positive knowledge. It is meantime more attractive to speculate than to deny; so why not seek further ways of searching for planets around other suns of this vast stellar universe? And returning to our own life-world, since it, after all, makes what it can of its particular range of interaction with solar and terrestrial environment, why not some such appropriate and adaptive activities elsewhere? Even on this earth life is more protean than we commonly realise; witness those strange bacterial forms which vegetate and synthetise in ways chemically quite outside those of others, and still more of our ordinary plant-world. And again, if our human thought ranges out into the Universe, can such thought be all there is? Let us at least keep our thought open. Who knows what may befall?

CHAPTER IX

EVOLUTION

HISTORY OF EVOLUTION THEORY

VAGUE GREEK EVOLUTIONISM.—The general idea of Organic Evolution is that living creatures have come to be as they are from relatively simple beginnings by a gradual process of racial change. This idea is congruent on the one hand with individual development and on the other hand with human history; and therefore one expects to find it expressed in ancient times. And so it is, for a *vague* evolutionism is stated by many of the old thinkers, such as the Greek Philosophers. Thus Empedocles seems to have thought of the Becoming of Life as gradual, of plants appearing before animals, of the imperfect being gradually replaced by the perfect, and, most remarkable of all, of the extinction of the imperfect being a condition of the rise of the perfect. The last idea approaches the theory of Natural Selection. It must be admitted, however, that most of the ancient philosophers were very abstract in their evolutionism. When they condescended to the concrete, they seem to have pictured a gradual Becoming of a mysterious nature,—successive births from the earth's fertile womb. They had not the modern idea of one species giving rise to variations which form new species, the old and the new often living on together. Fine expositions of the old Greek evolutionism will be found in H. F. Osborn's *From the Greeks to Darwin*, and Zeller's *Griechishe Vorgänger Darwin's*. It should be noted that according to some authors, such as Edward Clodd in his *Pioneers of Evolution*, the Greek philosophers were nearer modern evolutionism than they usually get credit for. But analogy in thought is sometimes mistaken for homology.

ARISTOTLE.—As Aristotle had an intimate knowledge of many animals, and probed into such apparent minutiæ as the eye of the mole and the early development of the chick, he may well have thought of Organic Evolution, and much more concretely than his predecessors. As a matter of fact he was very reticent on the subject, though he seems to have pictured an age-long genetic advance. "Nature can only rise by degrees from lower to higher types." "Things, being continually moved by a certain principle in themselves, arrive at a certain end." This is an early expression of the often recurrent idea of an inherent perfecting principle, which is not very far from one of the modern theories—that of "orthogenic variation", i.e. of progressive change along a definite line. It is

interesting to notice Aristotle's anticipation of the idea of the struggle for existence: "Animals are at war with one another when they live in the same place and use the same food. If the food be not sufficiently abundant they fight for it even with those of the same kind." Reference may be made to G. J. Romanes, "Aristotle as a Naturalist", *Contemporary Review*, vol. lix, p. 275; D'Arcy W. Thompson, *Aristotle as Biologist.*

ADUMBRATIONS.—No doubt the general idea of evolution was in the background of many minds, century after century, but there has been, we think, a tendency to overstrain the recognition of adumbrations. Thus the case for Giordano Bruno as evolutionist seems to us very unconvincing, and the same may be said in regard to other so-called precursors. Even if we take Lucretius, he was an evolutionist in the sense that he gave a poetic picture of a process of gradual Becoming, both cosmic and animate; yet he was not an evolutionist in his theory that living creatures arose by successive stages from the bosom of Mother Earth. Of the modern view of one species arising by variation from another, he had no suggestion; in fact he was nearer Milton's creationist picture of the lion pawing its way out of the earth. Yet Lucretius had an anticipation of a struggle for existence in which animals work out their destiny. For after speaking of their courage, craft, swiftness, and utility to man, he writes: "But those to whom nature has granted none of these qualities, so that they could neither live by their own means, nor perform for us any useful service, in return for which we should suffer their kind to feed and be safe under our protection, those, you are to know, would lie exposed as a prey and booty of others, hampered all in their own death-bringing shackles, until nature brought that kind to utter destruction."

EVOLUTIONIST PHILOSOPHERS.—The evolution of theories of evolution is bound up with the whole progress of the world; and the rehabilitation of evolutionism that may be associated with the Renaissance was doubtless the outcome of many factors. Evolutionist ideas were beginning to be applied to other orders of facts, notably in regard to the earth and the solar system; Biology itself was beginning to arise, as in the classification of Ray and the embryology of Harvey. There were arousing changes in human life which must be taken account of—the collapse of the feudal system, the increase of travel and the discovery of America, the invention of printing and the founding of Universities, and many more besides. In the seventeenth and eighteenth centuries the distinction between philosophers and scientific investigators was not so painfully marked as it is to-day, but it is noteworthy that the evolution-idea was for a long time more at home among the philosophers than among the

naturalists. As Osborn says: "It is a very striking fact that the basis of our modern methods of studying the Evolution problem was established not by the early naturalists, nor by the speculative writers, but by the Philosophers." He refers to Bacon, Descartes, Leibnitz, Hume, Kant, Lessing, Herder, and Schelling. "They alone were upon the main track of modern thought." Leibnitz and Kant were much nearer to Darwin than were mystically-minded naturalists like Lorenz Oken (1779–1851). The roll of honour of pioneer evolutionists has been unnecessarily crowded.

PRE-DARWINIAN BIOLOGICAL EVOLUTIONISTS.—The first naturalist of distinction to give a broad and concrete exposition of Organic Evolution was Buffon (1707–88); but it is interesting to notice that his contemporary Linnæus (1707–78), although protagonist of the counter-doctrine of *the fixity of species*, went the length of admitting (in 1762) that new species might arise by intercrossing or hybridisation. This was a sign of the breaking-up of the ice. Buffon had a splendid genius, which he mistakenly called "a supreme capacity for taking pains"; he was a disciplined mathematician, who translated Newton's *Fluxions*; he took all Nature for his province, and had evolutionist views not only of plants and animals, but of the solar system and of the earth's sculpturing as well; he was strongly convinced of the unity of Nature and of *l'enchainement des êtres*. Unfortunately his position is somewhat obscured and weakened by his apparent—deliberate or timid—vacillation between his own scientific conclusions and the orthodoxy of the Sorbonne. But he realised (1) the struggle for existence and the elimination of the unfit, (2) the influence of isolation and artificial selection, and (3) the modifying action of changes in food, climate, and surrounding influences in general. As regards the factors in the process of Organic Evolution, Buffon's general position might be indicated by calling him an *environmentalist*: thus also a main founder of ecology.

Erasmus Darwin (1731–1802), evidently influenced by Buffon, was a thoroughgoing evolutionist, believing that all the diverse forms of plants and animals were descended from a few ancestral forms, perhaps even from one "vital filament". He thought that evolutionary change was mainly due to the exertions which living creatures make to preserve or better themselves. Animals are driven to endeavour by hunger, love, and the need of protection. Thus Erasmus Darwin's chief factor in evolution was change of function, not of surroundings. "From their first rudiment, or primordium, to the termination of their lives, all animals undergo perpetual transformations; which are in part produced by their own exertions in consequence of their desires and aversions, of their pleasures and their pains, or of irritations, or of associations; and many of these

acquired forms or propensities are transmitted to their posterity." Thus Erasmus Darwin is nearer to Lamarck than to Buffon.

Lamarck (1744–1829) was scientifically much more important than Buffon or Erasmus Darwin, but we are here following a chronological order. He was a learned botanist and zoologist, with an enthusiasm which a terribly keen struggle for existence never conquered; he had no small success in orderly classification—of Invertebrate animals in particular; he had a restlessly speculative mind, more philosophical or synoptic than his two great predecessors. Lamarck's *Philosophie Zoologique* was described by Haeckel as "the first connected and thoroughly logical exposition of the Doctrine of Descent"; and to that must be added that the suggestiveness of Lamarck's particular theory of evolutionary change has not yet been exhausted. New surroundings evoke new needs, and new needs involve new functions or habits. "Such and such parts, formerly less used, are now more frequently employed, and in consequence become more highly developed; new parts also become insensibly evolved in the creature by its own efforts from within. These gains or losses of organic development, due to use or disuse, are transmitted to offspring, provided they have been common to both sexes, or to the animals from which the offspring are descended." These two propositions, translated by Samuel Butler from the *Philosophie Zoologique*, are fundamental, yet they are not quite adequate. For at times Lamarck makes it clear that the new need ("besoin") which makes itself felt may be something subtler than increased appetite seeking satisfaction, subtler than increased energy seeking vent; it may be definitely *psychical*—the animal's "bent bow", its endeavour after well-being, its urge towards self-expression. Lamarck's causal theory of evolutionary change was thus not only biological, it was psychobiological; and to this more unified view of life, his critics, usually of strictly physiological and morphological outlook, necessarily fail to do justice, as in so commonly reducing his doctrine to little or nothing more than a naïve faith in the transmission of acquired characters.

ILLUSTRATION OF EVIDENCES OF ORGANIC EVOLUTION

LOGICAL POSITION OF THE IDEA OF ORGANIC EVOLUTION.—According to the general idea of Organic Evolution, which Darwin so fully brought into intellectual currency, our present-day fauna and flora have arisen by natural processes out of an antecedent fauna and flora, on the whole somewhat simpler and more generalised, and so on backwards through the ages until we lose clue after clue, and find ourselves in the thick mist of life's beginnings. While there have been occasional retrogressions and degenerations, and many

an extraordinary complexifying (as among sponges and corals) without real advance, and many extinctions of fine types (such as the Pterodactyls or Flying Dragons), there has been on the whole an emergence of progressively more differentiated and more integrated forms of life. And organic evolution implies not merely that, say, modern crocodiles arose from more generalised extinct crocodilians; it implies the emergence of distinct novelties, such as insects from non-flying ancestors, or birds from a terrestrial stock of bipedal reptiles.

The logical position of the general idea of Organic Evolution is not like that of the law of gravitation or the laws of the conservation of matter and energy, where experimental verification is readily forthcoming. The evolution-idea suggests a genetic description of how organisms have come to be as they are, and its validity rests on the way it fits the facts. It defines *a certain mode of becoming*; and there are no data which are in any way discrepant or contradictory. Although zoologists do not at present know the gradations by which the first known bird (Archæopteryx) arose from an extinct reptile stock (probably the order of Pseudosuchia), no competent zoologist doubts that birds evolved from reptiles. And although there is great difference of opinion among zoologists in regard to the causal factors which operated in the evolution of birds, there is no hesitancy in saying that the evolution-idea is, so far as it goes, a broadly satisfactory formulation of the mode of becoming that has actually taken place.

An illustration from the study of individual development may be of service. For centuries it was believed that various parasites could arise "spontaneously" within their host, and the larvæ of flies within the exposed flesh. The descriptive formula of the mode of becoming was "Spontaneous Generation" or "Abiogenesis". But through the patient work of many naturalists, from Redi to Pasteur, it became quite clear that the parasites and the maggots arose from parents and from eggs in the usual way, though sometimes disguisedly. Thus the descriptive formula of their mode of becoming was recognised as the old and familiar term *Development*. This remains quite convincing even though there are still many cases where the stages in the life-history are inadequately known, and although no embryologist can say more than a little in regard to the factors operative in the developmental process. So is it in regard to racial evolution.

EVIDENCES OF EVOLUTION.—Every detail of botany and zoology that has been carefully studied admits of evolutionary description, and more than one specialist has offered to vindicate the general idea of Organic Evolution without going beyond the class or group to which he had given particular attention.

Thus all the facts of botany and zoology are "evidences of evolution".

It is useful, however, to indicate some of the sets of facts that point in a peculiarly impressive way to the Evolution-idea. As these have been restated many times since Darwin marshalled them in his *Origin of Species* (1859), a summary treatment will suffice here.

(*a*) GEOGRAPHICAL.—Since it was on the voyage of the *Beagle* that the evolutionist view of Nature was vitally borne in on Darwin's mind, it is fitting to begin by referring to the geographical evidence. Darwin was, he tells us, greatly impressed by the number of extinct ground-sloths (Megatheriums and Glyptodonts in the order Edentata) to be unearthed in South America, which is the modern headquarters of the sloth and ant-eater order. This correspondence between the extinct and the extant in the same area is eloquent. "This wonderful relationship", Darwin wrote, "in the same continent between the dead and the living will, I do not doubt, hereafter throw more light on the appearance of organic beings on our earth, and their disappearance from it, than any other class of facts."

On the equatorial Galapagos Islands, which Darwin visited at the age of twenty-six, he found ten different kinds of giant tortoise on ten adjacent islands, and five kinds in different corners of the largest island, which is called Albemarle. What could it mean but that isolated groups of an original stock, marooned on a volcanic peninsula that became an archipelago, varied in slightly different directions on the different islands, and that isolation prevented any pooling of the new departures? The same holds in regard to the land lizards of the genus Tropidurus, for nearly every island has a peculiar species; yet of the unique marine lizard, *Amblyrhynchus cristatus, that can swim*, even from isle to isle, there is but one kind, though there is also a non-aquatic relative called Conolophus. Can we wonder that Darwin felt himself "brought near to the very act of creation"?

In further development of such strong geographical evidences consideration should be given to the fauna of oceanic islands (see Wallace's *Island Life*); to the widespread distribution or representation of archaic types, like the Lung-fishes (Dipnoi), the Lancelets (Amphioxus), the King-crab (Limulus), and the relatives of Peripatus; and to detailed cases like the geographical distribution of the Marsupials, which are now for the most part restricted to Australia, though once with a much wider range.

(*b*) PALÆONTOGRAPHICAL.—Many great events must have occurred in the ages now represented by Pre-Cambrian and Cambrian rocks which are relatively poor in fossil remains, but admitting this we cannot but be impressed with the disclosure that the rock-record makes of a gradual ascent of life. In Ordovician and Silurian times the only backboned animals were the fishes; ages passed and Amphibians appeared, with their first footsteps in the Devonian and

their climax in the Carboniferous. Then in the Mesozoic periods was the prolonged Golden Age of Reptiles, from amongst which the Birds and the Mammals gradually arose. The most general of all palæontographical facts is perhaps the most impressive as an "evidence of evolution"—namely, the successive emergence of nobler and finer forms of life.

The palæontological argument includes the occurrence of "connecting links", such as the first known bird, Archæopteryx, from the Jurassic, which, though feathered and in other ways distinctly avian, was reptile-like in having teeth in its jaws, a long lizard-like tail, a half-made wing (i.e. without a fused carpo-metacarpus), claws on three fingers, and such a convincing little detail as

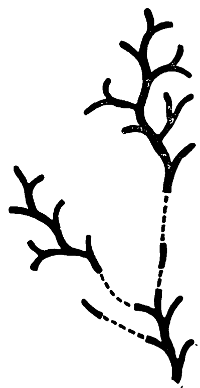


FIG. 156.

Hint of Part of a Genealogical Tree in which there has been repeated dichotomy or bifurcation, as indicated by the small twigs, which may represent species or genera or families. The dotted portion indicates the absence of annectant types in the lineage or pedigree. After Döderlein.

"abdominal ribs", which recall those of crocodiles and many other reptiles.

Very striking also are the fossil series which link species to species, as is so well illustrated by the Tertiary species of the freshwater Snails Paludina and Planorbis. Form A is distinguishable at a glance from form Z, but the gradualness of the series which connects them is very remarkable. Thus in the *Planorbis multiformis* series there is a strikingly smooth transition from a high spiral to a flatly coiled disc (cf. Fig. 138).

On a larger scale, the series of fossil horses, elephants, camels, and Ammonites are convincing to all open-minded students.

(*c*) MORPHOLOGICAL.—It is one of the most instructive of biological lessons to compare a series of, say, fore-limbs in some detail —e.g. of frog, turtle, crocodilian, bird, bat, horse, and man.

For in spite of their great diversity of shape and use, they are strictly homologous. There are many structural differences, a loss of this and an exaggeration of that, but the large fact is the recurrence of the same fundamental bones, muscles, blood-vessels, and nerves. Everything is new, and yet everything is old; the same material is fashioned into varied guise. There is no possible interpretation of this except the evolutionist one, that we are dealing with a genetic series of blood-relations.

Similarly, what other interpretation can be put upon the frequent occurrence of vestigial structures (separately discussed), or on

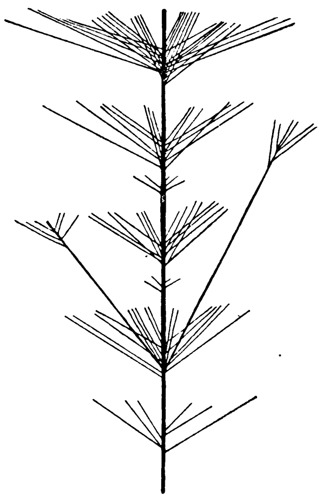


FIG. 157.

Another Mode of Branching of a Genealogical Tree. After De Vries. At different levels of the main stem, from successive plastic stocks, there has been an abundant whorl-like radiation of species in many directions. The two long lateral twigs show how types originating at a lower level may surpass in their individuation the types on the next higher level or whorl.

"Nature's way" of making a very new thing out of something very old? We must guard against the fallacy of supposing that one species or even organ is transformed into another; what has happened has been the emergence and divergence of one species from another by means of new departures or mutations, and the origin of one organ out of another which evolved something novel out of the old. The elephant's trunk was a striking novelty, which took a long time to reach its modern perfection; yet what is it but an elongated nose, plus a piece of upper lip? Such intricate novelties as the sting of a bee and the spinnerets of a spider must be traced back to a commonplace origin as abdominal limbs.

Not to be forgotten is the possibility of drawing at least the outline of a genealogical tree, of linking class to class by means of

synthetic types, and of bridging the gaps between discontinuous species by collecting sports or mutations.

(*d*) EMBRYOLOGICAL.—In many cases the life-history of the individual is a condensed recapitulation of the presumed history of the race. The embryonic development of many an organ, such as brain, heart, and kidney, is a re-treading of the racial evolution. Even the gradual growth of a much-branched nerve-cell in a bird or mammal has its later stages represented by the final forms reached, but not transcended, in reptile, amphibian, and fish. In a very real sense the frogling climbs up its own genealogical tree; and the way in which antique structures, such as gill-slits, outlive their usefulness, leaves one with the alternative—Evolution or Magic?

(*e*) PHYSIOLOGICAL AND ACTUAL.—Besides geographical, palæontological, anatomical, and embryological "evidences", there are others which may be grouped as physiological, actual, and experimental. Thus the transfusion of blood may be effected harmoniously between organisms which are on other grounds (e.g. anatomical) believed to be near relations. The closeness of the relationship, e.g. among Primates, may be measured by the amount of the precipitate which follows the mixture of the blood of different types. The test-tube shows visibly how near the gorilla is to the orang, but how far from the baboon.

The whole story of domestication and cultivation is an experimental corroboration of the theory of evolution, or rather of the evolutionist way of looking at the present. The past lives on in the present; but, more than that, in many a corner of the world, as we have illustrated in reference to the Foula Mouse, evolution is going on under our eyes.

To sum up, the general idea of organic evolution is that the present-day living creatures have arisen naturally by gradual change from ancestors on the whole simpler, just as tame pigeons have arisen from wild rock-doves, or races of cabbages from Wild Kale.

Evolution may be defined as a continuous natural change in a race in a definite direction, in the course of which new departures emerge and may, according to their value and viability, be established alongside of, or gradually in place of, the originative stock.

The evidences include all the facts of life, since all admit of evolutionist interpretation, and there are none that contradict this. The evolution idea is a key that fits all the locks into which we are able to insert it.

Since the "evidences" have been often well stated—by Darwin best of all—we have restricted ourselves here to an outline; and to this we now add two or three illustrations in greater detail.

FURTHER ILLUSTRATION OF EVIDENCES OF EVOLUTION

VESTIGIAL OR RUDIMENTARY STRUCTURES.—In many organisms, plants as well as animals, there are abundant illustrations of more or less useless structures which are evidently the survivals of better developed ones seen in ancestral types, or in related species which are indicative of these. Darwin compared them to the functionless or unsounded letters in words like le*o*pard and de*b*t—words whose history would be more difficult to read if they were spelt lepard and det. He compared them also to the functionless buttons and buttonholes and many other structures in man's clothing, whose historical significance is easily recognised. Others have compared them to useless survivals, such as sinecure offices in social organisations. As the word rudiment is also used to denote the beginning of an organ (the *primordium*, or German *Anlage*), it is clearer to keep the term vestigial, which suggests a trace or relic, for more or less functionless and relatively minute structures which are functional and well-developed in related types. It is desirable to say "more or less" functionless; not only because small organs, like the pituitary body, which were once regarded as useless, are now known to be of great physiological importance, but also because it is very difficult to prove that any living structure is quite useless.

EXAMPLES.—(*a*) The third eyelid in man and monkeys is a small tag of connective tissue in the inner upper corner of the eye. It sometimes includes a minute piece of cartilage, the *plica semilunaris*, and it is larger in some races than in others. It is a persistent vestige of the third eyelid or nictitating membrane, which is well-developed in most mammals (as also in birds and reptiles),—a mobile structure that is used in cleaning the front of the eye. In man and other Primates, this third eyelid is no longer needed for this function, for the upper eyelid has become much more mobile than in other mammals. In Cetaceans, again, the third eyelid is absent, which may be correlated with the fact that the front of the eye is continually washed with water. A well-developed third eyelid may be seen in most common mammals, such as rabbits and dogs; it may be readily observed in birds, flicking across the eyeball.

(*b*) In the ear-trumpet or pinna of man there are vestigial muscles —the relics of those that move the ear of many a mammal, such as the horse. In most individuals these muscles are never activated; yet it is not very unusual to find a man who, beginning young, is able to move his ears. The dwindling is connected, directly or indirectly, with the mobility of man's head, so that the location of a sound is determined by a movement of the head as a whole,

whereas the horse standing on the street effects the same orientation by moving its ear-pinnæ and nothing more.

We shall give no other examples from man's museum of relics, but refer to Wiedersheim's *Structure of Man* (1895), where an almost complete list, amounting to over a hundred, is given, the length of the list being largely due to the inclusion of numerous vestigial muscles, such as the traces of the skin-twitching panniculus carnosus, which is well-developed in many mammals, such as the horse.

(*c*) Adult Cetaceans have no externally visible hind-limbs, yet there are internal vestiges of several bones, with which muscles are associated. In some cases there are relics of hip-girdle, femur, and tibia, partly cartilaginous and partly bony. A large whale, thirty feet long, may have a vestigial hip-girdle of a little over a foot. It is not known that the associated muscles are of any use; the vestigial pieces of skeleton are buried very deeply beneath the blubber; and the hip-girdle relic is not connected with the vertebral column. In very young embryos of the porpoise and of a few other Cetaceans there are actually *external* traces of the vanished hind-legs.

(*d*) At the junction of the small and large intestine in many birds there are two blind tubes or cæca forming culs-de-sac on the course of the alimentary canal. In a duck, for instance, they are as long as one's hand; and they have the usual function of cæca, that they delay the food on its downward passage, affording longer opportunity for digestion and absorption. But if we examine a pigeon instead of a duck, we find two minute projections less than a quarter of an inch in length—too small to be of any appreciable use. They illustrate clearly what is meant by vestigial structures, for every possible gradation is found between the immense cæca of the ostrich and their almost complete absence in an eagle. The reduction to a vanishing-point may be correlated with the specialisation of diet and the raising of the digestive function in birds to a very high level of efficiency, as is indicated by the small amount of undigested residue, the waste that accumulates in guano islands, for instance, being mainly renal excretion.

(*e*) In no snake is there any trace—even embryonic—of a pectoral girdle and fore-limb, but there are occasional vestiges of a pelvic girdle and hind-limb. Thus in the pythons there are two spurs about half an inch long projecting from the under surface just in front of the cloaca. As it is possible that these may be of use in the union of the sexes, or even in climbing, we shall not insist on them; but there are other cases where the total size is so minute that no one can suggest utility.

A recent study of the snake's vanishing hip-girdle has been made by Prof. J. E. Duerden and Mr. R. Essex, of Grahamstown, the subject being a black snake called Glauconia. It is a burrowing

insectivorous creature, about six inches long, often found under stones in South Africa. There are two minute spurs, each supported by a bone corresponding to the thigh or femur; but these spurs are buried in the tissues and never project. Therefore we may assume that they are not of any use.

(*f*) On the back of the skate's flattened head, just behind the eye, there is a large opening or spiracle, by which the water used in respiration passes into the pharynx, to be driven out by the five ventral gill-clefts. This spiracle is the first gill-cleft (hyo-mandibular), turned dorsally instead of ventrally, and used for the intake, not for the outflow, of water. It is not in the slightest degree vestigial, and as we have noticed elsewhere it has a particular interest in being the homologue of the Eustachian tube of Amphibians, Reptiles, Birds, and Mammals. But if we look into the spiracle of the skate we see on the anterior wall a comb-like structure with parallel ridges. There is no doubt that this is the residue of the first gill, the ridges corresponding to the gill-lamellæ, but the whole structure is so small and slight that all function has gone. It is a typical vestigial organ.

(*g*) The familiar shell of a snail is represented in the Cellar Slug (Limax) by a minute plate of lime hidden on the animal's back, and in the Carnivorous Slug (Testacella) by a sprinkling of calcareous granules, while in the Black Slug (Arion) there is no vestige at all. Similarly, the beautiful chambered shell of the Pearly Nautilus, in part of which the animal lives, is represented in Spirula by a not less beautiful, yet minute and internal, chambered spiral. The animal is not in it, but it is in the animal. Perhaps it may serve as a strengthening internal support, like the sword-like vestiges in sepia and squid; yet it must be noted that the Octopus type is highly successful, although no trace of a shell is left. It may be pointed out that there is in almost all molluscs an embryonic shell-sac with a microscopic shell, but this does not correspond to the subsequent mantle-made shell that we have been discussing here.

Let us take another remarkable example, the Watering-pot bivalve, Aspergillum, which has become adapted to a sedentary life in a burrow. The tubular shell is the length of one's middle finger, with a diameter like that of a fountain-pen, and the upper end is closed with a disc perforated like the rose of a watering-can. Near this end, if we look carefully, we see plastered on and immovable a pair of minute valves, the original valves of the bivalve—obviously quite functionless. This is a peculiar case, where the exaggerated growth of a secondary shell has incorporated the original one and made it useless; so this now finds its place among vestigial structures.

(*h*) Among Arthropods there seem to have been many instances of appendages becoming small, and then being transformed so that they became suited for a new function; but there are other cases where the dwindled part has no known use. The first pair of abdom-

inal limbs of a female crayfish are much reduced, very variable, and of no observed function. A hermit-crab clings to the central pillar of its borrowed whelk-shell by means of a terminal pair of abdominal appendages (uropods). In the male there are three other abdominal limbs (pleopods). confined to the left-hand side and very slender. As far as we know they are quite useless in the male. In the female, however, the appendages of abdominal segments II, III, and IV, though confined to one side, are of considerable strength and serve to carry the eggs. This again is an interesting case, that what is apparently useless in the one sex should retain in the other a very important function.

A pair of transformed abdominal appendages may form an egg-laying organ or ovipositor in a female insect, and this may be re-transformed into a sting, naturally unrepresented in the male; but there is no question of an ovipositor or a sting being vestigial. On the other hand, in some other insects, there are reduced paired appendages at the end of the abdomen for which no use is known. They are probably true vestigial structures. Similarly with the three pairs of mouth-parts in insects, which, however transformed, are always made up of mandibles, first maxillæ, and labium, there are frequent reductions of parts to what may be almost literally called "vanishing-points". Thus moths and butterflies have vestigial mandibles, not known to be of any use in the adult.

VESTIGIAL STRUCTURES IN PLANTS.—In some flowers that have lost their radiate symmetry and become bilateral, as in Scrophularias, one of the five stamens has become a useless vestige; and there are many similar instances. Sepals and petals may sink below the limit of useful size, and a leaf may be reduced to a mere scale. One must be careful, however, to note that great reduction of size does not necessarily imply that the structure is vestigial; for the concept "vestigial" implies uselessness.

TRANSIENT BUT USEFUL EMBRYONIC STRUCTURES.—

From true vestigial structures, which we are trying to discriminate more precisely, we must distinguish reduced embryonic structures which still have their use during development, but do not come to anything in adult life. (*a*) The primitive dorsal axis known as the notochord arises in development as an axial differentiation of endoderm cells along the dorsal middle line of the gut (archenteron) of the Vertebrate embryo. It is the only dorsal supporting axis in primitive Vertebrate animals like lancelets and lampreys, and it is in varying degrees persistent in some fish types, such as the sturgeon and the mud-fishes. In most cases, however, it becomes surrounded by a mesodermic sheath which develops into the backbone—the notochord's substitute. From Bony Fishes to Man the adult supporting axis is the mesodermic backbone which replaces the endo-

dermic notochord, of which there are only residual traces in the adult. But the point is that the notochord is always quite clear in the embryo, and although it may be called vestigial in the adult, who dare say that it is useless in the embryo? It may serve as a useful temporary scaffolding around which the backbone is built up; it may be that a backbone could not arise in individual development without an antecedent, though evanescent, notochord.

From this set of cases must be excluded those purely embryonic or larval organs which give no evidence of having been much reduced. Thus the "shell-breaker" or "egg-tooth" of most birds is a minute transient organ which helps in breaking through the shell and then drops off soon after hatching; but there is no evidence that it ever was larger. But as noted above, the embryonic notochord of higher Vertebrates is relatively much reduced. The cement-organ of a tadpole is a very small structure which is not carried on beyond the tadpole stage, but we have no warrant for saying that it ever was more than larval.

PERSISTENCE OF USELESS STRUCTURES IN EARLY DEVELOPMENT.—Another useful distinction is between true vestigial structures persisting in adult life and purely embryonic useless structures which find expression in the embryonic stages only. They persist apparently because of "hereditary momentum". Their hereditary "factors" are present as part of the ancestral inheritance, and they give rise to parts which are of no known use, and yet of no harm. They are all instances of an apparently useless recapitulation of the past. Thus the embryo scorpion (Euscorpius) has no fewer than seven pairs of abdominal limbs, indicated by minute projecting plates. The second pair persist into adult life and form the genital operculum; the third pair become the well-innervated "combs" or pectines; while all the others disappear without leaving a trace. They are not known to be of any functional significance; they do neither harm nor good; they are embryonic relics of ancestors which had many well-developed and useful abdominal appendages. Similarly, an embryo spider may show six pairs of abdominal appendages, of which the last two develop into the spinnerets, while all the others disappear. What can be said except that a persistence of ancestral "factors" or "genes" leads to an early developmental expression of six paired appendages, two of which persist into adult life in very useful guise, while four disappear like melting snow.

TRANSFORMATIONS OF STRUCTURES.—This is a mode of organic evolution of fundamental importance, and will be treated separately, as it deserves. The reason for including a reference to it in this sub-section is simply that many of the transformed organs

have previously been subject to reduction. Thus a bee's sting is a transformation of a *reduced* pair of abdominal appendages—so much reduced, indeed, that they are unexpressed in the male sex. Similarly, the spinnerets of the spider, very elaborate structures indeed, are transformations of *reduced* abdominal appendages. Similarly the Eustachian tube is a transformation of a reduced gill-cleft. But the results of these transformations are obviously not vestigial.

ONTOGENETIC DEGENERATIONS.—Between the inhalant and exhalant apertures of an Ascidian there is a small nerve-ganglion, the only nerve-centre in the adult body. This is the residue of part of the anterior end of the central nervous system of the free-swimming larval Ascidian. Yet it is not in the ordinary sense a vestigial structure, not merely because it is of physiological importance, but because its final state is involved in a thoroughgoing retrogression or degeneration of the larval Ascidian. Granting that no part of the body lives or dies to itself, we may draw a distinction between the racial retrogression of a particular structure in a progressive animal, like the hip-girdle of Cetaceans, and the racial retrogression of a great part of the body in direct or indirect correlation with some drastic change in the mode of life, such as becoming sedentary or parasitic.

ARREST OF DEVELOPMENT.—Perhaps it is not carrying the analysis too far to suggest that vestigial structures should be kept apart from particular arrests of development that can be definitely connected with some peculiarity of environmental, nutritional, or habitudinal nurture. Thus the eye of Proteus, a newt of the dark Dalmatian caves, is in a sense vestigial. It does not appear on the surface of the adult's head; it is very small; and it is imperfectly finished. But if the larvæ are reared under red light in the laboratory, the eye increases in size and differentiation, makes its way to the surface, and becomes a seeing eye. The development of the Proteus eye is arrested, doubtless, by the absence of the liberating stimulus of light, but this seems a different state of affairs from the vestigial condition of the spiracular gill of a skate, or the vestigial condition of the phalanges of the second and fourth digits in the modern horse. These are represented in the embryo horse by minute nodules ("buttons") which fuse on to the distal ends of the second and fourth metapodials, these being themselves reduced to mere splint-bones.

INCIPIENT STRUCTURES.—Finally, in this long-drawn-out list of distinctions between true vestigial structures and appearances that may simulate them, we must be on our guard lest a minute and half-finished structure is a beginning, not an ending;

a primordium, not a vestige. This may be true, for instance, in regard to the electric organ found by Cossar Ewart at the root of the skate's tail. It may be the dwindled relic of a well-developed electric organ such as is possessed by the not distantly related Torpedo of the Mediterranean. But it is much more likely to be a transformation of muscular and nervous tissue that has not yet come to its own.

PROBLEM OF ORIGIN.—When we ask how a structure may become vestigial, the historically oldest answer is that it follows from disuse or from long-continued defective nurture. Thus it is said that a Cetacean has lost its hind-legs as the direct result of not using them, the tail serving as a very efficient propeller. The mole has a much-reduced and very imperfect eye, as the direct result, it is said, of taking to a subterranean life. In the individual lifetime a disused organ sometimes dwindles, as we know in the reduction of the size of the fibres in a muscle which is not exercised. Functional activity is needed if an organ is to keep up its normal size and efficiency. The theory is that reductions directly due to disuse and deficient nurture are hereditarily entailed, and gradually bring about a racial dwindling of the particular organ concerned. This view will be discussed in connection with the general problem of the Transmissibility of Acquired Modifications.

The second theory is that quantitative germinal variations, plus and minus, are very frequent, and that a reduction in the size of a part may be a positive advantage in certain conditions of life. If the animal has become sedentary a reduction of those muscles that are no longer important will economise space, energy, and formative materials. Thus variants in the direction of the reduction of the useless will be more successful and will lead the race towards simplification. The degree of eye-development is a variable quality in many animals; if there was a trend of germinal variation towards eye-reduction or eye-weakness, and a dark environment became available, it is quite possible that there would be survival value in dwindling eyes. For not only would the relatively blinder forms be less likely to find their way out again to an illumined environment for which they were ill-suited, but the possession of a relatively simplified and reduced eye would lessen the risks of injury. It may be that germinal variations in the direction of reduction proved themselves profitable in the struggle for existence; and it is quite gratuitous to handicap this theory by refusing to recognise that a well-endowed active organism is in the way of testing its own qualities by unending tentative and experiment.

But, thirdly, the case of Proteus plainly indicates that for both the theories, which we may call "Lamarckian" and "Darwinian" for short, it is useful to take account of the nurture of the *individual*. For the experiments with Proteus show that its pale, wan colour is

not due to the absence of pigment-forming factors, since a Proteus well illumined may become dark in a week. What is lacking is the liberating stimulus of light. The same holds, even more dramatically, for the eyes. The Proteus is blind, partly perhaps because its eye primordium is *ab initio* lacking in developmental vigour, but partly because the absence of the appropriate liberating stimulus causes in each individual an arrest of development.

PERSISTENCE OF ANCESTRAL HABITS

Darwin was very characteristically interested in the dog's not infrequent habit of turning round and round on the hearthrug, as if to smooth down the herbage and make a comfortable bed for the night. It has been occasionally seen when a country-dog goes to sleep among the grass, and it is a habit among wolves, from which domesticated dogs are derived; and the habit has lasted for many thousands of years since Neolithic Man first succeeded in making the dog his partner. No doubt the habit of turning round and round would be useful in ancient days before there were houses in the modern sense, but it has long ceased to be necessary, and yet it persists. It illustrates the hand of the past on the present. Perhaps there is also some significance in the fact that the past asserts itself in this case in the *sleepy* dog, when the unconscious has more chance to exert its influence than in wideawake hours.

The same survival of habits is seen when the well-fed dog buries a bone or some remains of its meal, for this is a wild trait seen, for instance, in the fox. Another thing we have all seen a dog do, is scratching backwards with its hind feet, as if to throw earth over its excrement. It no longer succeeds in doing this; and there is obviously no sense in scratching, as it often does, on a bare pavement. The past lives on, and a habit may outlive its usefulness.

Darwin gave a number of instances of habit-survival in his book on *The Variation of Animals and Plants under Domestication* (1868); and there is an interesting book by Robinson on *Wild Traits in Tame Animals*. Let us bring together some examples.

Some cattle were transported from Aberdeenshire to a Californian ranch, where they found themselves in relatively wild conditions. It was observed that when a cow calved away from the farm, which is not favoured in Britain, she hid her calf in a thicket when she went out to graze. This hiding of the calf is a wild habit, which had remained dormant for many generations of men and cattle, but had reasserted itself when there was a change towards more natural surroundings. Here it may be recalled that cattle disturbed when at rest rise on their hind legs first, while horses rise on their front legs first; part of the explanation being that the wild horses

rest in the open plain and the wild cattle under the shelter of the forest or thicket. More convincing, we think, is the persistence of the mare's habit of giving her foal many short drinks, while the cow gives her calf a very long drink at a time. There is a physiological reason for this, as for the way an animal rises, but both have also to do with habits and surroundings, and the difference becomes more intelligible when we recall the fact that the troop of wild horses shifts often from place to place, and that the foal has to stagger after its mother soon after birth, so that a big meal would be inappropriate. But it is different with the calf hidden away in the thicket, to which its mother returns to chew the cud. For our present purpose the interesting fact is the persistence of the difference in habit after it lost no small part of its significance in conditions of domestication.

Why does a horse shy? At a sudden rustle in the hedgerow, or before a wind-borne ball of paper, it suddenly swerves and may unseat the careless rider, or even upset the gig. There can be little doubt as to the meaning of this nervous trick. It is almost certainly a reawakening of an ancient "reflex", that is to say, an involuntary automatic jerk, which would save the wild horse from being bitten by a snake or pounced on by some lurking carnivore. The profitable reaction in ancient days was to make a sudden swerve away from the rustle or movement. Sometimes, no doubt, the individual horse is very high-strung, and sometimes there has been an individually experienced scare; but for most cases the historical interpretation is sound. The hand of the past on the present is not dead, but living.

We must not think of these reawakenings as like our own recollections, where genuine memory is concerned. For true memory is the mental revival of a previous individual experience, such as an image, or an impression, or an idea of some sort. But the shying horse on the road and the sleepy dog on the hearthrug illustrate an enregistration of their ancestors' experience, not a memory of their own. No clear-cut dividing line can be drawn in such cases between the bodily and the mental, but the grip of the past that we are illustrating has doubtless more to do with inborn nerve-and-muscle linkages than with the revival of mental images. Let us take more examples.

The donkey is the domesticated descendant of the Wild Ass of North Africa, and its unwillingness to cross the smallest stream of water is probably a persistent outcrop of prejudices and preferences established long ago in the dry desert. Perhaps its fondness for rolling in the dust has a similar historical origin; but there is no need to overwork the idea. Darwin wrote: "The same strong dislike to cross a stream is common to the camel, which has been domesticated from a very ancient period. Young pigs, though so tame,

sometimes squat when frightened, and thus try to conceal themselves even on an open and bare place."

Domesticated sheep are the descendants of several species of wild sheep, such as the mouflons of Cyprus, Corsica, and the East; but except when they are lambs they seldom show much of the adventurousness and intelligence of their ancestors. Man is largely to blame for this, as some exceptional breeds show; for he has usually bred for wool and for mutton, not for brains. When any of his sheep persisted in being enterprising and original, he removed them from his flock by the simple process of eating them, and thus he has succeeded in evolving an ultra-docile, if not even stupid, race. Furthermore, as the playful lambs prove in later life, there is a depressing and dulling influence in an over-sheltered life. Domesticated sheep are protected from all enemies; even the wolf has become a protecting dog. There is no danger except from snowstorms; and where there is no danger there is apt to be degeneration.

Among domesticated sheep we see some interesting instances of the grip of the past. Everyone familiar with a varied country-side must have noticed how fond sheep are of chewing the cud under the shelter of a low rock or against a bank broken by rabbit burrows or the like. In short, they seek out a position where they cannot be easily disturbed from behind. We may be sure that they do not think this out, for they have no enemies nowadays to be afraid of in a country like ours. Moreover, they often choose a place where there is no real protection from a rear-attack, only a suggestion of a protection. The interpretation is prehistorical, and takes our thoughts back to the fear that the wild ancestors had of carnivores. For herbivores of relatively small size the profitable habit is to graze rapidly in the pasture, and then return to the shelter of the rocks where they cannot be surprised from behind, and where they can chew the cud in peace. This is why sheep persist in huddling against the steep bank of the bunker on the golf course.

When wild sheep are passing quickly in single file along the side of a mountain, the routine rule is that they must all do what the leader does. If he or she jumps over a narrow but deep fissure or the like, all must do the same without hesitation. This saves time and trouble, but it is a quaint survival when it is illustrated by sheep going along the street of a town. It is often possible to see the succession of little jumps travelling along a file of sheep. Another interesting reawakening is seen when a ewe is going to give birth to a lamb, especially if it is for the first time. There is an *instinctive prompting* to get away from the flock, and the ewe will sometimes force herself through a difficult hedge to get away from her neighbours. This is characteristic of the wild sheep. Another piece of behaviour that we see at lambing time on a sheep-farm is that the ewe scrapes with her fore-feet as if to make a little bed or cradle for

the lamb that is to be born. This was useful for her ancestors who lived in rough places, but it is not needed on the modern sheep-farm.

INSTINCTIVE PROMPTINGS—These two words give us the clue to the whole matter. Think again of the "gimmer", that is to say, a ewe that is about to lamb for the first time. She does not know what is going to happen, but she obeys an inborn, hereditary prompting to a certain routine of behaviour. It is quite easy to prove that she does not understand what she is doing, for she is often very much startled at the appearance of the lamb, and will even run away afraid. But if she once licks the lamb there is an instantaneous release of a series of maternal instincts, and she allows it to suckle. Yet she does what she does, not because she understands the situation, nor because of a recollection, but because part of her inheritance is a series of *instinctive promptings.* There are pre-established linkages between certain nerve-cells and certain muscle-cells, and once the trigger is pulled the behaviour follows. No one is wise enough to say how soon or how far the creature becomes aware of what it does, and how soon there are ripples of emotion as well as nerve-thrills and muscle-contractions. But we must try to understand that instinctive promptings are inborn or hereditary, ready-made inspirations, which do not require any learning or apprenticeship. They are as much part of the racial inheritance as the convolutions of the brain, or the shape of the teeth, the strength of the heart or the crinkliness of the hair.

THE HAND OF THE PAST ON BIRDS.—Darwin tells us of the Musk-duck (*Dendrocygna viduata*), that in its native country and wild state it often perches and roosts on trees, a very unusual thing for a duck to do. Now it is very interesting that domesticated Musk-ducks, though very sluggish birds, are fond of perching on the tops of barns and walls. If allowed to spend the night in the henhouse, the female will generally go to roost beside the hens, though this may mean leaving the drake, who is too heavy to mount so high.

There is a significant old story of a race that was arranged between a flock of domesticated geese and a flock of domesticated turkeys, which were to be driven for miles along the highway. The farmer who arranged the race put his money on the geese, and knowing the habits of the two kinds of birds timed the contest so that the turkeys would be passing under an avenue of trees about nightfall. The turkeys were driven off at a great pace, and the geese lagged behind. But it was a foregone conclusion in favour of the geese. For when the turkeys reached the part of the road where there were trees they flew up and roosted among the branches, whence they could not be driven. The European turkey is in great part at least

derived from the American Wild Turkey (*Meleagris gallopavo*), which roosts in high trees. The wily farmer knew that the old instinctive prompting was sure to assert itself.

Why does a hen make such a fuss when she lays an egg? It sounds like an almost hysterically proud excitement; but it is obviously open to the criticism that if the laying is in the open the cackling advertises to possible enemies the whereabouts of the egg. The plausible interpretation is historical. The domestic fowl is derived from the Wild Jungle Fowl (*Gallus bankiva*) of India, a gregarious bird of the forests. The flock moves about after food, and the cackling is probably useful in making it easier for the hen, that has been separated off during the egg-laying, to rejoin her companions. Her call is answered, and she hears where they are.

ANCIENT TRAITS IN YOUTH.—Beautiful instances of habit-survival are seen in the play of young domesticated mammals, e.g. kittens, puppies, lambs, kids, and calves. It has been shown by Groos and others that playing among animals is of value as an irresponsible apprenticeship to the serious business of life, and as an opportunity for testing variations in habit before consequences are too critical. Thus we understand why wild kittens and otters should play at hunting and sham-fights, while wild sheep and goats play at "Follow my Leader" and sham-races. Play is in some measure the young form of work. But for many domesticated cats that have given up hunting, and for most domesticated sheep that have given up adventure, the playing activity has lost a great part of its meaning. Yet it illustrates how the living influence of the past may exert itself in youth, though weakening as the animal reaches the age of discretion.

AS TO HABITS AND HABITUATION.—A frequent cause of obscurity is the double use of the word "habit." When intelligently controlled behaviour, such as playing an instrument or riding a bicycle, recurs many times, it becomes easier and easier; it requires less and less attention and control, it illustrates *habituation*. The transmission of nervous impulses along certain lines becomes very easy, so easy that the whole succession of steps may follow almost automatically if the first one is taken. This is habit-forming in the strict sense; it is an individual acquisition—an automatisation—and thus an economy—of what required, to begin with, much attention and possibly much intelligent control. It is unfortunate that the same word is often used for acquired longings and cravings, and desires which we call "bad habits", and it is not less unfortunate that the same word is used for the customs and ways of animals, as when we say that Fabre devoted his life to studying the habits of insects. These customary doings or ongoings, as they might be called, are

sometimes very varied and plastic, controlled by intelligence at every turn, as is true of many of the ways of otters, foxes, and monkeys. Or they may be predominantly instinctive, as in the ways of ants, bees, and wasps. Or it may be that an animal's behaviour includes a good deal that is more or less intelligently *learned*, along with a good deal that is *instinctive*. Whenever a customary activity has become so thoroughly engrained in the animal's constitution that its performance requires no apprenticeship or learning, then the animal may be more free to make experiments; and many birds and mammals show a happy mixture of instinctive behaviour (in the wide sense of inborn or enregistered) and of intelligent behaviour in the sense of profiting by experience and showing something in the way of judgment. This is an intricate subject which we cannot pursue further here (*see* Animal Behaviour section), but the important point is that wild traits in tame animals are always of the enregistered or instinctive type, never of the intelligent type. This is why they sometimes last on in domestication after their original utility is past; they are part and parcel of the hereditary constitution. It is not that new habits acquired under the conditions of domestication oust old habits which were established in the wild life of ancestors, for this is using the word "habit" in two different senses. The grip of the past on the behaviour of domesticated animals is illustrated in reference to little ways which were enregistered in the nervous system and formed part of the racial inheritance. The little ways, like the dog's turning round and round before it falls asleep, cannot suddenly disappear any more than the power of speech would disappear in colonists who found themselves in a country of the deaf and dumb.

AN ILLUSTRATION OF THE EVOLUTIONARY SURVEY OF THE ANIMAL KINGDOM

A taxonomic classification aims at grouping organisms according to their affinities or "blood-relationships"; and it is based, as we have seen, on homologies or deep resemblances in structure and development. But behind this systematic arrangement, no easy task in itself, there is the more difficult problem of interpretation. Can the evolutionary alternatives and trends be detected—even with plausibility—which have resulted in the at first sight bewildering manifoldness among the forms of animal life? If we think of the various phyla, classes, orders, families, genera, and species as arranged on a complex genealogical tree, can we discern in any degree the mode of branching? Such is the ambitious task which we wish now to illustrate.

THE FUNDAMENTAL DICHOTOMY.—In every organism, as we have

already seen, there is building-up and breaking-down, repair and waste, assimilation and disassimilation, income and expenditure, anabolism and katabolism. This is a common-sense fact—the complementary balance of feeding and working, of stoking the engine and burning the fuel. It is also a fundamental fact of biochemistry, that metabolism has these two aspects—constructive or anabolic, and disruptive or katabolic. Every living creature must keep a balance between these antithetic processes, but the ratio of the two, $\frac{A}{K}$, varies greatly from type to type, as well as in their own lives, the condition being that for the general maintenance of life the numerator must always be kept greater than the denominator. The continual "winding up of the clock" is characteristic of life, but in many organisms the clock runs down very quickly, in others very slowly. Thus there is the contrast between relatively active and relatively sluggish types. But a very active animal, like a typical bird, must have much more anabolism for its weight than a sluggish reptile, for it has to balance its intense katabolism; so the contrast should always be stated as a ratio. Measured for a short time, the ratio $\frac{A}{K}$ for a flying bird will be less than that for a sluggish reptile of the same weight, although the numerator for the bird will be greater for a week than it is for the reptile.

The fundamental dichotomy among organisms, leading on to secondary and tertiary dichotomies, is just this divergence between the relatively more active or katabolic and the relatively more passive or anabolic. It may be discerned between plants and animals, which typically differ from one another as munition works from active batteries. In virtue of their photo-synthesis, elsewhere discussed, green plants have extraordinarily preponderant anabolism; they make and store abundance of reserves of energy which animals may eventually utilise in energetic, sometimes almost explosive activity. This contrast between plants and animals has exceptions, of course, but they prove the rule by their rarity, such as the semaphoring Telegraph Plant (*Desmodium gyrans*) of the steamy Ganges basin and the female cochineal insect heavily laden with her store of carmine. Some flowers, like the "Calla Lily," have a temperature, and a massive coral has far more lime than living matter, but neither of these is in any way typical.

All through what we can discern of the past evolution of animals we see the same forking of the ways. It stands out in the contrast between a sluggish Sporozoon, like the Monocystis parasite of all the common earthworms, and an intensely active Infusorian like the Noctiluca that sets the waves on fire in the short summer darkness; between the sedentary corals in their thick-walled castles of indolence

and the free-swimming, aggressive, luminescent Portuguese-Men-of-War; between the fixed rock-barnacle, attached head-downwards, wafting its food into its mouth with its curl-like appendages, and the frolicsome shrimps and prawns; between limpets and sea-butterflies, sea-slugs and octopuses; between the fixed ascidian and the lightly-built pelagic salps; between tortoise and Flying Dragon; between reptile and bird; between the ground-sloth and the bat flying high. No doubt all sorts of secondary adaptations, e.g. to different habitats and diets, have to be taken into account; but to begin with there has been, we think, a fundamental divergence between the relatively anabolic and the relatively katabolic. the more conservative and the more adventurous, the saving and the spending habit.

It is of interest to look at a summary mapping out of the great phyla and classes of animals to see that even the larger divisions illustrate our thesis.

<table>
<tr><td colspan="3">Birds</td><td colspan="3">Mammals</td></tr>
<tr><td colspan="2">(Lizards)</td><td colspan="2">Reptiles</td><td colspan="2">(Tortoises)</td></tr>
<tr><td colspan="3" rowspan="2">Fishes</td><td colspan="3">Amphibians</td></tr>
<tr><td colspan="3">Cyclostomes</td></tr>
<tr><td colspan="3">Lancelets</td><td colspan="3">Tunicates</td></tr>
<tr><td colspan="2" rowspan="3">(Insects, etc.)
Arthropods
(Crustaceans)</td><td colspan="2">Enteropneusts</td><td colspan="2">Molluscs</td></tr>
<tr><td colspan="2" rowspan="2">(Errantia) (Sedentaria)
Annelid Worms</td><td colspan="2">Brachiopods</td></tr>
<tr><td colspan="2">Polyzoa</td></tr>
<tr><td colspan="2">Ctenophores</td><td colspan="2">Unsegmented Worms
(Turbellarians) (Cestodes)</td><td colspan="2">Echinoderms</td></tr>
<tr><td colspan="2">(Medusæ)
(Medusoids)</td><td colspan="2">Cœlentera</td><td colspan="2">(Corals)
(Zoophytes)</td></tr>
<tr><td colspan="2" rowspan="2">(Infusorians)</td><td colspan="2" rowspan="2">(Rhizopods)
Protozoa</td><td colspan="2">Sponges</td></tr>
<tr><td colspan="2">(Sporozoa)</td></tr>
</table>

One sees at a glance the possibility of arranging the more active types, like Infusorians, Ctenophores, Arthropods, Lancelets, Fishes, Birds to the left and the more sluggish types, like Sporozoa, Echinoderms, Brachiopods, Polyzoa, Molluscs, Tunicates, Amphibians, and Mammals to the right, while other great groups like Cœlentera and Reptiles illustrate both extremes, and others again like Rhizopods and "Worms" are, as it were, on a *via media*, neither very active nor very sluggish, but a compromise between the more pronounced rights and lefts. And in a class like that of the Polychæt

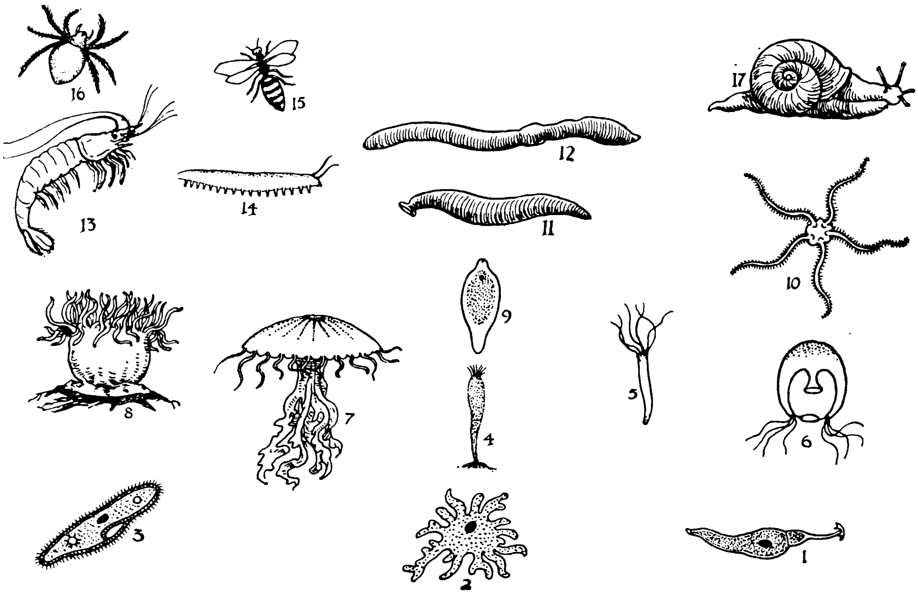


FIG. 158.

A Survey of Invertebrate or Backboneless Animals. 1, A parasitic protozoon, a gregarine; 2, an amœba; 3, an infusorian, Paramœcium; 4, a very simple vase-like sponge; 5, a simple polyplike hydra; 6, a medusoid or swimming-bell; 7, a jellyfish or medusa; 8, a higher polyp or sea-anemone; 9, a liver-fluke or trematode; 10, a brittle-star, one of the echinoderms; 11, a leech; 12, an earthworm; 13, a prawnlike crustacean; 14, Peripatus; 15, an insect; 16, a spider; 17, a snail.

Annelids, the active "errant" types like Nereis are contrasted with the passive sedentary types like Serpula and the coral-like Filigrana, just as Lizards with Tortoises at a higher level.

Let us suppose for the moment that this grouping is neither fanciful, nor the projection of a personal theory, what contribution to biology does it make? It suggests that the main mode of branching of the genealogical tree has been dichotomy after dichotomy, sometimes with intermediate types between the divergent lines, and that the fundamental reason for the divergence is simply that these are the great metabolic alternatives. In other words, the most frequent of all variational alternatives is to increase or decrease the

ratio between anabolism and katabolism, measured for a representative length of time.

We may bring this into line with the theory of our *Evolution of Sex* (1889), that the sex-divergence depends on the rate and rhythm of the metabolic routine, the female or egg-producer being an organism in which the ratio of anabolism to katabolism $\left(\frac{A}{K}\right)$ is greater than the corresponding ratio in the male. (See section on Sex.) It would make for unity of outlook if we could regard the contrast between Plant and Animal, Sporozoon and Infusorian, Coral and Jellyfish, Sea-slug and Sea-butterfly, Amphibian and Fish, Mammal and Bird, as analogous to the contrast between Female and Male: and indeed that has from the outset been in our minds. See also our *Sex* and our *Evolution* (Home University Series).

Delaying once more, and deliberately again, we see throughout the flowering plants, alike in orders, families, genera, and species, the dichotomy between the more vegetative and the more floral, between the grasses and the orchids, both literally and metaphorically, between the "weeds" and the "flowers" as the insight of common folk discerns. The grass type with inconspicuous flowers is pre-eminently foliar, covering the earth like a garment; the orchid type is pre-eminently floral, with relatively insignificant vegetation. sometimes indeed dependent to no small degree on its mycorhiza (*q.v.*). We are not of course suggesting any direct or recent dichotomy between Gramineæ and Orchidaceæ, since they are well known to be through a long past on different lines of evolution, e.g. with superior and inferior ovary respectively; we are suggesting something deeper, that the divergence towards grassy and towards floral types expresses a variational alternative of a fundamental character, analogous to that between coral and medusa, between typical reptile and typical bird, even between female and male. So grass and orchid are for us at extremes of an early dichotomy among their monocotyledonous ancestors; while the also now very dissimilar rushes and lilies started upon their dichotomy, now so well marked, from a common type, from which they are still in principle comparatively little removed.

And if it be said that everyone has always known that there have been and are emphatically more active and emphatically more sluggish animals, pronouncedly more foliar and pronouncedly more floral plants, we must reply that this commonplace has not been biologically appreciated as indicative of fundamental variational alternatives, and that the prevailing analogy in the manifold expressions of the dichotomy has not been recognised. Open secrets are often missed.

But we are not suggesting that evolutionary divergences are all simply dependent on the see-saw between preponderant anabolism

and predominant katabolism; there have been many other forkings of the way; yet some of them are at least dimly discernible as recurrences of these fundamental alternatives. We think of the contrast between the single-celled and the many-celled; between the radially symmetrical and the bilateral; between the soft-mouthed, feeding on microscopic particles and organisms, and the hard-mouthed, feeding on materials that demand jaws; between vegetarians and carnivores; between the instinctive little-brained animals and the more intelligent big-brained animals; between cold-

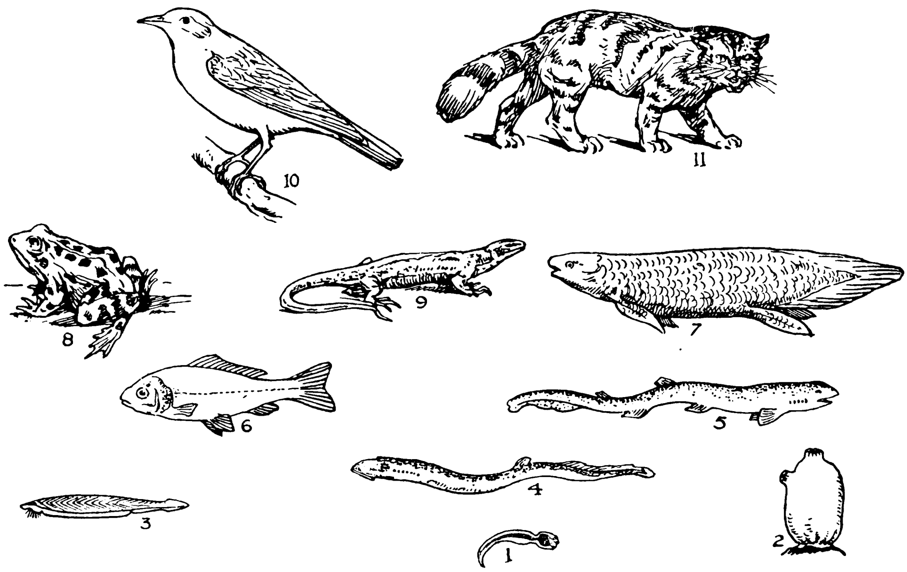


FIG. 159.

Bird's-eye View of Vertebrate or Backboned Animals. 1, One of the permanently tailed small Tunicates, allied to Appendicularia; 2, a typical degenerate Tunicate or Ascidian; 3, a lancelet or Amphioxus; 4, a lamprey or Cyclostome; 5, a dogfish; 6, a bony fish or Teleostean, like the cod; 7, the Australian Mudfish or Lungfish, Ceratodus; 8, a frog, a type of Amphibia; 9, a lizard, a type of Reptilia; 10, a typical bird; and 11, a cat, a typical mammal.

blooded and warm-blooded, between low blood-pressure and high; between depression of or exaggeration of this or that endocrinal gland—a contrast which extends, in part at least, to that between phlegmatic and excitable, placid and sanguine, cautious and adventurous. How many or how few of these and other biological antitheses can be correlated with the fundamental $\frac{A}{K}$ ratio, we do not yet venture to say; but more than may at first sight appear. For this apparently simple statement of the ratio $\frac{A}{K}$ is traceable into very intricate expressions: as with simple rhythm to complex dance, so is it with life.

EVOLUTION OF PROTOZOA.—Keeping in mind the idea of the Cell-Cycle (*q.v.*), we see that the phylum of the Protozoa, which includes half a dozen or so classes, needs to be envisaged, from our physiological-evolutionary point of view, as illustrating the varying preponderance of each of these three chief possibilities of cell-life —great activity such as the Ciliate and Flagellate Infusorians display, great sluggishness as characteristic of the encysted Sporozoa, and an intermediate line of life, neither very active nor very passive, but in a general way more or less amœboid, that of the Rhizopods or Sarcodina. What objections can be raised against this way of looking at the facts?

Consider it more fully. It may be pointed out, as an objection, that in the class Proteomyxa, which are in many ways primitive, even in sometimes lacking a nucleus (cf. Haeckel's "Monera"), (1) there may be flagellate spores which may become amœboid; (2) several small amœboid units ("amœbulæ") may fuse into a larger mass as in Vampyrella and Protomyxa; (3) and that a cyst is formed around one unit or more, whether as a protection against drought and the like, or as a preliminary to spore-formation. Thus in this class of Proteomyxa, or even in a single type, like Protomyxa, there may be flagellate, amœboid, and encysted phases. But this is what might be expected among primitive organisms, which have not yet taken predominantly to any one line of cell-life. Nothing could be wished better to confirm us in the conception of the cell-cycle. And this cell-cycle theory expressly recognises plasmodium formation, as a multiple conjugation, and thus reappearing in various forms not necessarily related.

Secondly, it may be pointed out by the critic that the suggested physiological rationale of the usual classification does not appear to him to work well in detail. Thus although Sporozoa are predominantly sluggish, often laden with reserve products, and frequently encysted, (*a*) they have in many cases flagellate reproductive units (as in some Coccidians). Again (*b*) the sporozoites of the malaria organism are for a time amœboid, and (*c*) the same organism has microgametes that resemble spermatozoa. (*d*) Transitory pseudopodia occur in many Flagellates (e.g. Oikomonas and Dimorpha) and permanent pseudopodia in a few (e.g. Mastigamœba). (*e*) Among Radiolarians flagellate zoospores are the rule, and also known to occur in some Foraminifera and Heliozoa. This list of cases, which seems at first sight damaging, if not even contradictory to the theory of three main physiological trends, might be greatly enlarged. But what we suggest is not that the acquirement and predominance of a flagellate, an amœboid, or an encysted habit excludes the possibility of such passage to another phase, but rather the very opposite. It is what we should expect, from our general theory of the nature of the cell-cycle; and also as a recapitulation of ancestral

features in development. Again, there may be phases of adaptive value, as for lying low in times of cold or drought; and again for fertilisation. This has been referred to in connection with the cell-cycle (*q.v.*). Our thesis is simply (*a*) that the existing classifications of the Protozoa show a number of classes, which we interpret as each characterised by a predominance of one of the main physiological alternatives and its corresponding form-type of cell-life; (*b*) that this predominance is not necessarily exclusive, but simply more fully acquired in some forms than others.

Thirdly, the critic may raise the difficulty that the class of Ciliated Infusorians (Ciliata) is morphologically far removed from the class of Flagellate Infusorians (Flagellata or Mastigophora), beside which they should be ranked if the proposed physiological-ætiological interpretation is sound. In short, the systematists have abandoned the class Infusoria, pointing, for instance, to the fact that all Ciliata have dimorphic nuclei (Heterokaryota), whereas the Flagellata, like the Rhizopods and Sporozoa, have one kind of nucleus (Homokaryota). Our answer is simply that we have always maintained the distinction between the classes Flagellata and Ciliata, and seen that the two classes are not nearly related: or even of monophyletic origin. We simply see both as representing an accentuation of the highly active habit of life; with a metabolic ratio $\left(\frac{A}{K}\right)$, in which the katabolic processes lag much less markedly behind the anabolic ones than is the case in Rhizopods, and *a fortiori* in Sporozoa. We admit, of course, that we are at present so far arguing by analogy when we say that a Slipper Animalcule, one-hundredth of an inch long, is living more nearly up to its income than an Amœba of the same size. For quantitative measurements at this low level are not easily made.

Yet a common Amœba moves at the rate of 600 microns per minute, so that it would take towards three-quarters of an hour to traverse an inch, while Paramœcium, with its specialised cilia, could do this within a minute. It is doubtless at less physiological cost—that of swimming compared with creeping—that the Paramœcium traverses its inch, that is with less katabolism for that particular piece of work; but there can be little doubt in anyone's mind that the Paramœcium compared with the Amœba is the more active type; though he may not describe it in these physiological terms as a predominantly katabolic one.

Once more the critic may argue that Sporozoa are sluggish and rich in anabolic reserves because they are parasitic; that the Flagellates and Ciliates are active and agile because the majority are adapted to swift pursuit of food; and that many Rhizopods are adapted to gliding along on solid surfaces and that they have often to carry a relatively heavy shell, while others with vacuolated

cytoplasm drift as Plankton in the open waters. Our answer is: all these correlations function both ways, throughout development and later life. Parasites are sluggish and highly fed: but we often see their active larval forms settling down—which is getting sluggish—and feeding highly—as hungry, as well as in lack of food. And thereafter they settle into their new habits, often very increasingly with inactivity of other functions, as the degeneration of their organs shows. Again, in its active mobile state, the nascent cell-form *can* move swiftly, pursue its food, and so selectively advance in mobility, the amœboid form creeps, the resting can but absorb, so again selectively. And shell formation, calcareous or siliceous deposition, is reasonably to be associated with less activity, of excretion especially. (Bone cells, etc., are not the active ones.) Also that all these types are doubtless adapted in detail to particular habitats and diets, e.g. Noctiluca with its strong macro-flagellum, Radiolarians with their vacuoles, Foraminifera with their food-capturing network of interlacing filamentous pseudopodia, Gregarines with their semi-permeable cortex, and so on; but that there is something prior to all this, namely the establishment of physiological types—flagellate, amœboid, and encysted—which subsequently found their most appropriate habitats and were further differentiated in endless adaptive detail. Yet these phase-forms, in our view especially, need not be of single and common origin, but may arise again and again. Thus our interpretation is rather confirmed than shaken by these criticisms, and we adhere to our view that the grouping of the Protozoa conforms with the three main alternatives of cell-life; and especially when viewed as phases of the cell-cycle: while this again is rationalised physiologically, as outlined at the outset. This thesis might be followed further with illustrations of the same alternatives within the several classes and their orders.

We thus interpret the well-known Protozoan classes as but so many less or more enduring forms of the cell-cycle, and as becoming specialised on one or other level of functioning, and thus into their usual forms, and so again for most of, if not all, their life; yet often manifesting returns to this, both in individual adaptation to environmental change, or in reproduction, and in individual development.

The simplest way to interpret all this is no doubt to leave the old classes as monophyletic, distinguishing Flagellates and Ciliates as of early divergence.

But is not such a classification too simple, even to artificiality: and needing revision accordingly? To choose an extra case: since even in the extreme and encysted passivity of Gregarines the cell-cycle reappears in reproduction, why may not its motile or creeping forms, in favourable circumstances, give rise to their new phyla,

resembling the old ones? The Protozoa very probably are of polyphyletic origin, not monophyletic, and the Flagellate Infusorians apart from the Ciliate. Indeed, we conceive the cell-cycle as basal and ancestral to the Protozoa, and their main forms as its characteristic phasal manifestations.

THEORY OF VARIATION

Many years ago we were together, as student and teacher at Edinburgh, in the laboratory of what is probably still the largest and richest of university botanic gardens, with great collections and many gardeners; so that we had but as it were to rub the ring for attendant genii to appear with cornucopias laden with all the specimens we desired, and these often "from the back"—as we then called it! But next one went to a chair of a new University College, with no garden or gardener, save for lawn-mowing: so at first there was nothing for it but to take off one's coat and start laying out beds for natural orders around lawns previously flowerless. In so doing, came rediscovery of the great fact, too much forgotten in one's leisured student-life of botanic studies and teaching, and in fact since gardening in childhood—that painfully discovered by Father Adam and all his field-labour descendants since—that weeds grow apace, even in poor soil, and flowers need tending, even in rich. Thus to make the best of the worst portion of ground there was laid out a weed wilderness, of hugely exuberant Heracleums and the like, for striking contrast of verdure with the rest. Next came, and that emphatically, the simple reflection, again so familiar to gardeners from time immemorial, that the well-growing vegetables of a kitchen-garden, e.g. the cabbages and greens, the garden-peas, the Jerusalem artichokes, the potatoes, and what not, are also far more exuberantly vegetative, and less conspicuously floral, than are their congeners of the flower-garden, hardy though these often be, say the stocks and wall-flowers; and so for the sweet-peas, the sunflowers and other composites, or the more decorative Solanums; while many of the associated and well-flowering orders yield no utilisable vegetative surplus at all. In fact, then, the verdant kitchen garden is so highly vegetative, in comparison with that of flowers, as to be so far on the way to weed-like also. Thence, again, looking out into nature, the like contrast became more and more impressive, as that of grasses and trees, so vegetative in growth, yet relatively inconspicuous in flowering, with the oftener flowering shrubs, as these again so often surpassed by kindred herbaceous flowerers; and the like difference appearing again among kindred species and genera of these. Following up this simple line of thought, more or less implicit throughout gardening and

cultivation, one came to feel that this elemental physiological contrast—of more vegetative and more floral forms—had not been sufficiently realised and kept in view in our predominantly morphological systematic tradition; and next came conviction, that our science had as yet too largely been developed in urban fashion, and by botanists who had practically remained in its leisure class. For this, with all its advantage over the rustic in time for thinking, and in accuracy of thought so far as it goes—yet more or less loses sight of his physiological viewpoint, and his hard-earned life-experience of toilsome tending of the growth and blossom he respectively desires, as in forest, field, and kitchen garden on one side, to flower-garden on the other.

Given here the problem of laying out "the natural orders" as naturally as might be (yet within the limits imposed by buildings, and necessary drives and paths for these) came for instance the setting out of the monocotyledonous orders; and these arranged as far as possible with the most floral and strikingly developed to the right hand; in this case generally east of the observer, and the more vegetative—rushes, grasses, sedges, etc.—to the left, in this case west: and since the same contrast is next observable within each order, and often each genus, its species, and even varieties—to use as far as possible the same graphic convention for all these. Thus, beginning near the centre of this monocotyledonous range along an extended walk, one placed the Liliaceæ near the middle, with the splendid lilies on the right side, and the smaller flowered and less individually differentiated hyacinths on the other. On the right of the lilies the yet more floral and less vegetative tulips; and among these the comparatively bud-like "Darwins", to left of the ordinary more showy "feathered" and "flamed" varieties, and with the fantastically exaggerated (and more perishable) "Parrot" tulips to their right again. Beyond such floral Liliaceæ came the more differentiated Amaryllids, with, e.g., the Narcissus species and varieties again planted in the same way, from the simplest with many small flowers to daffodils of great corona within corolla. And so on, through allied and intervening orders, to the Orchids, as extreme towards the right.

For other familiar types, take first the Iris order (Iridaceæ) since everyone knows the Crocus, with its large and beautiful yet bud-like blossom; and beyond it the Iris, so magnificently open, and even with inner perianth (petals) thrown back. Beyond this, again, Gladiolus, with its magnificent raceme of great blossoms, less widely opened, but now bilaterally symmetrical. In Irises, as gardens show, there are many species of very varied range of flower-beauty, of which the commoner ones are the more hardy and vegetative, the rarer more varied in splendour and less leafy; and so for their garden varieties. The like for the garden Gladioli,

among which florists are annually surpassing each other. Yet note, as of Gladiolus type, the closely allied Montbretia, still beautiful, but smaller flowered, which in our northern gardens spreads in exuberance till it has to be weeded back from overpowering all around. Hence, then, our illustration of these two contrasted types:

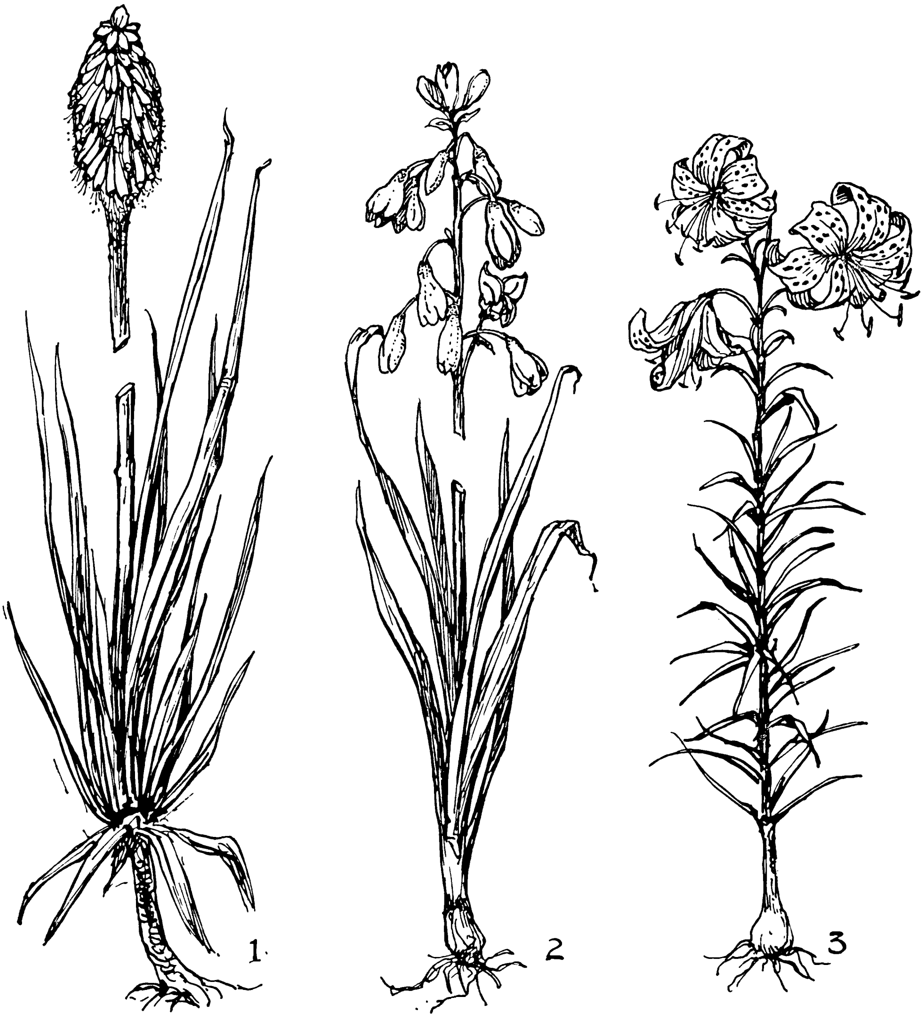


FIG. 160.

Contrasted Liliaceous Types. From specimens. 1, "Red-hot Poker," Tritoma, least floral of the three; 2, a related intermediate Galtonia; 3, a Tiger-Lily, most gorgeously floral.

Montbretia to left and a fine garden Gladiolus ("Marshal Foch") on right; and with an intermediate branching and less floral form of Gladiolus between. Here, then, even in very floral types, are examples of the contrast of more vegetative and more floral; and with such clearness as to suggest that this type of variation arises from the perpetually recurrent rhythm in life, between its two essen-

tial aspects, of self-maintaining and nutrition, and species-continuing reproduction; each tending to its finest developments, yet with perpetual minor interaction of these, into sub-rhythms of variations, often hard to trace and understand. In a way, then, we may thus

FIG. 161.

Contrasted Gladiolus-like Types. From specimens. 1, The more grassy, small-flowered Montbretia; 2, an intermediate type; 3, a very floral Gladiolus.

still speak of these as "spontaneous" variations, so long as we cannot trace out their intimate causes, yet not as merely "indefinite variations", since here we see an orderly rhythm of these fundamental life-conditions, not heretofore done adequate justice to on Darwin's and Wallace's line of interpretation of floral forms, i.e. as so many

independently arising and usually local and minor variations, separately adapted and coadjusted.

On this view, in fact, our whole conception of variation becomes a fully physiological one, and no longer so predominantly morphological or ecological as commonly heretofore: and this is strengthened by the introduction of florists' varieties, not usual in botanic gardens; yet this by no means merely for attractiveness, but for evolutionary teaching, by help of variations in manifest progress.

For further illustration, return to the Orchids, and recall that if we spend thousands on a fine collection we could in time of need scarce get enough starch out of them all for a single meal for one's gardener and oneself; whereas the same capital and labour, spent on more vegetative monocotyledonous allies, above all cereals and grasses, would have yielded us bread for many families, hay for many horses, pasture for many cows.

Even at a flower-show, besides the most gorgeous orchids, we see not a few of yellowish and greenish-purple blossom—and some of them almost green; and these with better-grown foliage than their near congeners, and of far more easy and abundant growth, as one has learned by experience, in planting a Himalayan hillside garden with such relatively grassy and well-growing forms.

Thus the popular impression of Orchids, as supremely floral, becomes a little prepared for the disappointing fact that our cultivated ones are but a few hundred among some six thousand species or more. Nothing is more striking in botanising in the Himalayan forests and glades than the contrast between the showy arboreal forms and the insignificant little patches of many terrestrial species, some even with such small grassy-looking inflorescences as at first to need the lens to make sure that they are indeed orchids at all; for the fine labellum we are so accustomed to is now reduced to little more than vestigial dimension, as well as its floral colour gone.

Yet among all the orchids at the show, what more magnificent and varied in colour than those of the genus Masdevallia, from most imperial purples to vividest orange flame, and often fantastic form as well? This group is indeed so striking and varied that, long before the war, when book production was less costly, its leading collector, the Marquis of Lothian, desiring to bring this genus more within reach of florists and botanists, and so with adequate wealth of coloured plates, found his monograph could only be produced for them at eight guineas! Yet Masdevallias have but a reduced and insignificant labellum; and their whole magnificence is thus but from the protean differentiations of the outer perianth. Hence is it not a reasonable inference that this genus is really but one of those many vegetative and degenerate ones above mentioned, which has however returned, by a reverse swing of life's pendulum, towards the ancestral floral type; and yet is limited by its degenerate past,

to finding new ways of making the best of the outer perianth which remained?

Illustrations of the reverse oscillation, from floral to vegetative, are more common. Recall the genus Helianthus, culminating for garden magnificence in the great sun-flowers, and yet so vegetatively exuberant in the kitchen-garden as "Jerusalem (*girasole*) artichoke" (*H. tuberosus*), with its subterranean wealth of potato-like tubers: so that in northern gardens it hardly ever flowers at all, and even in warmer midland France its flowers are late, and comparatively few and small. Is not this like the spendthrift turned to miser? A yet extremer contrast is that presented in the genus Asparagus, of which the common species, cultivated in Indian gardens, bears such exuberant wealth of white flowers wreathing the veranda columns as to show no foliage at all: while our European kitchen-garden species, cultivated for its succulent young shoots, grows up into verdant beauty, with only few and inconspicuous flowers. Yet these, on examination, betray the curious history that the apparent leaves are really flower-pedicels, on which the flowers all fail, while the true leaves below them are reduced to minute dry scales. Here have we not a fresh light on the variation process—that exaggeration of floral exuberance in a species or variety may tend to go too far, even to danger of extinction by overbalance; and yet that balance may in such cases sometimes be retrieved, and even towards the reverse extreme, that of the vegetative habit markedly predominant? And conversely also; for there are plants of such vegetative habit as sometimes to endanger, or almost lose, reproductive continuance by flowers. Yet this with less danger, since vigorous vegetative growth tends to asexual multiplication, as by creeping shoots, even to subterranean tubers, etc., or to vegetative inflorescence, as with various not uncommon grasses.

Space forbids the development of this line of interpretation throughout many of the orders of the botanic garden—and, indeed, of that far vaster Hortus Siccus, the herbarium. The recurrence of such oscillatory variation may be easily traced by the reader in either of these: and, indeed, the like extensively throughout the animal kingdom as well, as through gallery after gallery of the Natural History Museum; since recurrent in many varieties, species and genera, orders and classes.

Instead, however, of here further elaborating this, in the vast fields of Taxonomy, with which one might fill a volume, let us rather note how this mode of interpretation throws fresh light on other matters hitherto more morphologically or more mechanically interpreted, however truly enough so far. Take, for instance, the so-called "invaginated" inflorescence we know as the common fig, with its florets so completely enclosed; since, as all botanists agree, its original embryonic apex has been so fully overgrown by the

sides as to come to be at the bottom of the hollow thus produced. One may readily visualise such growth processes: (1) By putting one's elbows together on the table and joining hands vertically above it, thus roughly suggesting an ordinary shoot, with united finger-tips as growing point; and next (2) gently raising the hands and arms, but the elbows faster, so that these overtake the slower-rising finger-tips. We have thus a level, which (3) when the elbows are lifted farther and faster, becomes a concave depression, with the finger-tips below wrists and arms, and thus seeming pushed down to bottom, though really but of slower rise. We find less extreme forms of the like predominance of axial growth outrunning the cell-dividing and reproductive apex in many cases; thus Dorstenia, a herb of the fig order, has its inflorescence practically flat, or only at edges beginning its overgrowth. The broad though still convex apex of the crowded inflorescence which we popularly call a composite "flower" has arisen in the like way also, only not gone so far. So the long raceme of inflorescence of the probably ancestral bell-flowers (Campanulaceæ) seems thus to have been arrested by more precocious and less developed florets into the composite flower-head. It is here interesting to note how composite weeds have often small and insignificant flower-heads, like Groundsel (*Senecio vulgaris*) for commonest of weed type; yet its sister species (*S. cineraria*, with its buds so closely like heads of groundsel) flowers to exuberant beauty, yet needing gardening care and culture, and warmth also, to attain its perfection.

But returning to the form of flowers, the simpler orders, like the buttercup family (Ranunculaceæ) show the floral whorls (in this case really of surviving primitive spiral leaf-arrangement) in regular and normal descending order, with stamens distinctly below carpels (hypogynous) and petals and sepals in like order again. But in the Rose, see how the lower portion of the axis has outgrown its apex, so that the carpels are inside its almost fig-like cup, and the stamens, carpels, and sepals are uplifted (epigynous) in their due order, yet practically level around its upgrown margin. For intermediate form, see the strawberry flower with its parts on level (perigynous). On this principle, of reproductive checking of growth, it is thus not surprising that in utterly distinct cryptogamic tribes we find the like upgrowing and overgrowing: witness the saucer-like spore-case-bearing surface of Peziza, or its analogues in many lichens, to the completely enclosed "fructifications" of the Gasteromycetes. The principles of flower-making, as we may call them, are thus more general and physiologically intelligible than they have generally so far seemed.

No popularisation of botany has been more successful, since Darwin's rehabilitation and extension of Sprengel's discoveries, than that of the inter-relations of flowers and insects; and also of

wind-fertilisation, of inconspicuous flowerers more especially, with the respective adaptations to these different methods also. So far well:

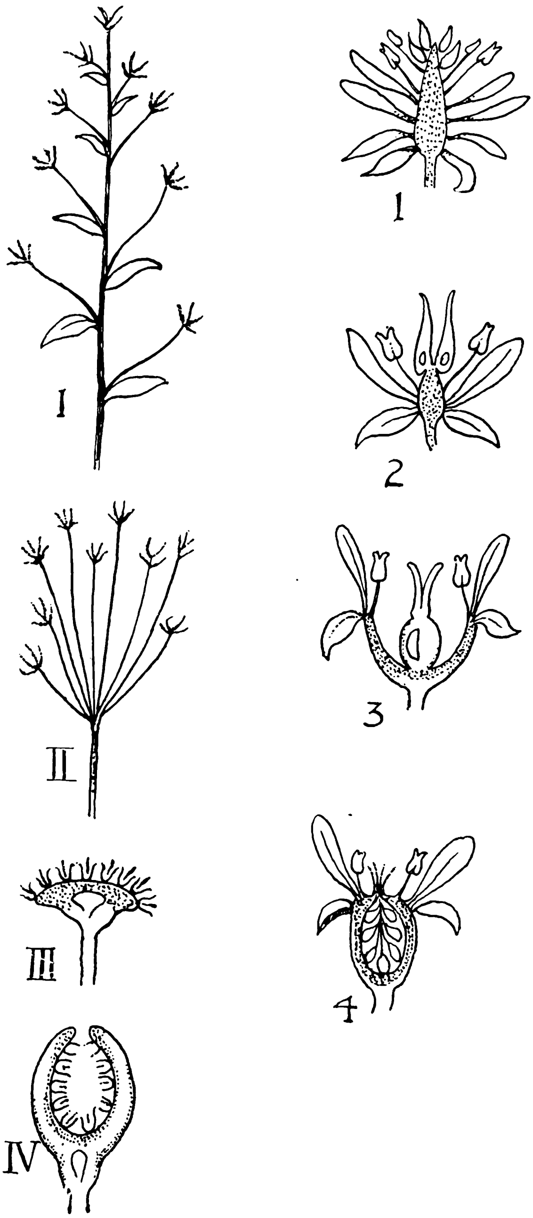


FIG. 162.

Changes Due to Shortening or Elongating the Axis. I–IV, a series of inflorescences; I, a typical raceme; II, an umbel, i.e. with axis not elongated; III, a capitulum; and IV, a fig. To the right, a series of flowers; 1, hypogynous with superior ovary, e.g. buttercup; 2, a shorter floral axis; 3, a perigynous, as in strawberry; 4, epigynous, as in rose, with inferior ovary, i.e. with the floral axis depressed.

yet the origin of all these by indefinite spontaneous variation and natural selection is no longer all-sufficient; if as here to the matura-

tion of anthers than by the (temperamentally vegetative) increasing length of their sustaining filaments; with their fuller exposure to sunlight and its aid in final maturation, as well as to wind, for their diffusion. This offered conception, of the interplay of vegetative and reproductive processes, we have long applied to the evolution of the sexes themselves, with the female as the more anabolic, and the male tending to katabolic preponderance, hence more active, though commonly shorter-lived. Everyone who knows the common diœcious plants, say the ground mercury (*Mercurialis perennis*) in the shaded dell, or the common red Lychnis often growing beside it, will soon learn to recognise the sexes at a distance beyond that needed for seeing their flowers, since the female plants are the better grown, with longer leaves of fuller green, and often more of them, since with shorter internodes despite their often greater height. The closely allied white Lychnis (*L. vespertina*) also shows this sex distinctiveness very plainly; but it can be more or less made out in diœcious plants generally.

VEGETATIVE "HABIT" OF GROWTH.—Extending this way of looking at growth, to the evolution of a characteristic vegetative "habit" of growth, we see behind the undenied and undeniably decisive importance, for extinction or survival, of natural selection, the organic normality of variation, and as often at least more clear: in fact as definite, and not merely indefinite. And as organically necessitated and urged; and thus "spontaneous" but in a deeper way than the older one so much left fortuitous; whether as small "variations" or larger "sports" or "mutations", though we are still far from explaining all these. Here it is well to note Darwin's cautious use of "spontaneous" and "indefinite" variations as essentially, for him, from causes not yet explained; so that our difference is more with less cautious Darwinians, who have too often taken these terms for granted, and his doctrine as all-sufficient accordingly.

Consider now the germinating plant, with its incipient shoot and terminal bud: Have we not here in principle and possibility the latent cabbage, or the palm-tree in miniature? See the rapid elongation of the tender shoot, with its long internodes, its beginnings of circumnutation; here in potential development are the climbers, the twiners, the great lianas. In its developing leafage, too, we see the beginning of the exuberance of growth, from grasses and weeds to rapid growing trees. In its developing lateral buds, we see their manifold branchings, whether below ground, as with so many grasses and more, or above it, in the trees. With haste to reproduction and flowering, we have the annuals; with which we can well imagine terrestrial vegetation began, while in biennials its first survivals of winter—thereafter easily prolonged, for in our Mediterranean garden many of our wallflowers are five years old, and with un-

exhausted promise. With delay of reproduction far greater growth is possible; and fuller flowering, as every orchard shows, and with more fruit accordingly. Yet after the strain of flowering is over, and before the fruit starts fully growing, there is a period of quiet and mature vegetation, of which so many evergreens give fullest developed examples. Is not the simple regular form of their leaves, so often ovoid or oval, a manifestly convergent evolution, reduced from often widely different and more elaborate herbaceous forms? For instance, in ivies, the strongly arborescent Scots and Irish varieties thus tend to quite simple leaves, though the commoner forms are still "ivy-shaped", i.e. with lobes recalling those of the elaborately developed Aralias, so decorative as evergreen foliage plants; while in the larger order of Umbelliferæ, to which these essentially belong, everyone is familiar with the elaborate beauty of their compound leaves. The like for many other evergreens, whose leaves are thus simplified by their slow and steady growth, in contrast to the exuberance of development common in their deciduous allies, presumably ancestral. That their survival is not so simply a matter of thickness and epidermic resistance as we were wont to assume, can be simply verified by observing that in a late spring frost, when young deciduous leaves are nipped, the young leaves of the common evergreen Euonymus, though still as thin and unprotected as deciduous leaves, conspicuously survive notwithstanding: so here the internal and constitutional quality of the evergreen's life must supplement the usual view, without, of course, disputing survival value to its thickness and epidermic defence in extremer cold, with snow, etc., as with mountain rhododendrons.

Again, though thorny plants have long been mainly explained in terms of defence against browsing animals, there is evidence as from the common gorse or whin (*Ulex europæus*) that thorny development is on one side a matter of constitutional habit, with active growth of shoot followed by more or less speedy ebb, and on the other of climatic adaptation; so increasing with heat and dryness, and abated in more favourable conditions. The frequent splendour of cactus flowering, despite leaf-reduction, is again associated with diminished vegetative intensity of growth; for though some attain large and even arborescent dimensions, they need long time for this. In summary, then, the plant is not too simply to be viewed as passive to environment, nor yet as exhibiting indefinite variations of adaptive value. Without denying some truth to each of these, we must also keep the plant in view throughout its phases of life-activity, from earliest to oldest (see *Curve of Life*), and recognise that its manifold variability bears definite relation to its constitutional yet variable balance and direction of self-maintaining and species-continuing energies, and these in the particular phase (or phases) of life which it may especially accentuate in its life

history. In a word, we must see it as an active being, and not merely as passive to circumstances; but as adaptive so far as may be from within, as well to without. If so, we must keep in view that natural selection does not act solely as favouring evolutionary progress, but may also restrain it. It may, on one hand, prematurely wield the shears of the third Fate, as well as on the other give helping and sustaining hand with the first and second. Darwin no doubt saw this; but by no means always his later disciples, whose optimism of natural selection, as all-sufficient explanation of evolution, needs

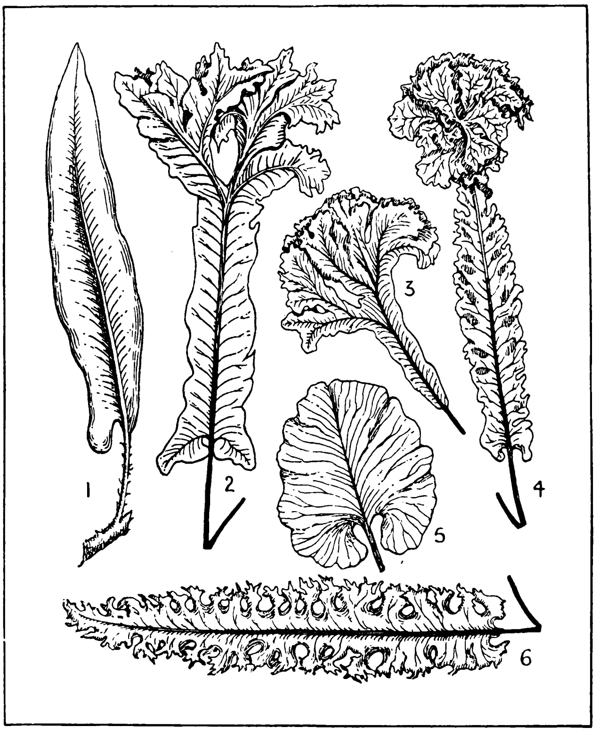


Fig. 163.

Variations (2–6) in Leaf-form in the Hart's Tongue Fern (*Scolopendrium vulgare*). The type is shown in 1. After Lowe.

this protest on the part of organic life, which has its own evolutionary springs within itself, and these not merely fated by ancestral heritage, deep-lying and important though that be. So surely also with the issues of that lifelong internal oscillation and struggle, of self-maintaining and species-advancing, and thence active adaptations, by which the issues of men's own lives, races, and histories have ever been modified and varied; with its issues accordingly, in his manifold developments and adaptations, too often towards extinction, yet normally endeavouring towards survival, and even advance.

What now for summary? Our botanic garden had among its old trees a fine large weeping-ash, which beyond its continued use as a

shady bower, served well to illustrate the evolutionary idea of the garden; as of the preceding pages, albeit in somewhat too pessimistic fashion. For the first rising, then drooping, branches could each represent the trajectory of life, and this not only for the individual but for many types of life as well, each running its course, and often to end at earth; yet ever recuperating itself, by giving rise to new branches rising higher, however they may later sink in turn. Yet we may also diagrammatise this more hopefully, as a perpetual divergence—like, say, that of *Aloe dichotoma* with its forking growth—here used to represent vegetative and reproductive predominance, yet with each of these capable of divergent branching anew. Or let us put this more simply in purely graphic form, with vegetative and reproductive predominances expressed as divergences towards opposite sides, yet these again—at stages and times—exhibiting counter-divergences, as from the floral orchids to their more vegetative and well-growing descendants, albeit less floral; and yet again from such more vegetative forms, the rise of more floral types anew, like Masdevallia above. Or, again, take other illustrative types above chosen, as the sunflower, or the flowery asparagus, reverting to more vegetative lives and forms. We may thus attempt such graphic expressions for each evolutionary group-history, with its rejuvenating possibilities in one way or other, as we come towards understanding it; and thus see that the stories of their lives, while agreeing in broadest general principle, may each have its own particular record; somewhat as on the wider level of human life-variability no two biographies or histories are alike in particulars, albeit often broadly akin in general.

We do not yet venture to offer here any full genealogical trees, as did the earlier evolutionists, like Haeckel, after Darwin's suggestive diagram in the *Origin of Species*: yet we have already recognised that for many groups there are now good ones, well substantiated so far as they go; so this present method may be found suggestive towards these and more, since broadly interpretative of many main divergences, and even also of minor ones, generic, specific, and varietal. And it will also be found that our larger concept of the life-process (E*fo* to *Ofe*) may be applied to such problems, in increasing number of cases. If so, we may reasonably hope we are on the way towards a further clearing up, not only of the principles of flower-making, but of the processes of variation and evolution more generally. Even from the above scanty outline, of too long delayed volumes, do not such methods of life-interpretation seem at least worth trial?

FURTHER ILLUSTRATIONS—PRIMROSES, ETC.—In this way we may review the natural orders of our botanic garden, their genera and species and varieties too, with freshened eyes. Since Darwin so admirably reinterpreted primrose-flowers, and demonstrated the

exact working of their "dimorphism"—of long-styled and short-styled forms ("pin-eyed and thrum-eyed", as children call them) in detail, and in relation to the fertilising insect, and also verified by his sowings the advantage of such inter-crossing, that subject has seemed settled for most botanists, as for long ourselves included. But with this additional physiological concept, of vegetative and floral oscillation and relative preponderance, do we not understand the matter a step more fully? For the long-styled Primulas are slightly the bigger and better growers, yet with not quite such large corollas: while this growth and flower difference becomes so well-marked in the Auriculas, as at once to explain why florists bring no pin-eyed forms to the flower-show. Again, the common and fine garden-variety of primrose with petaloid calyx ("Hose in Hose") is obviously far more floral than the variety with sepals developed as spreading leaves ("Jack in the Green"). These two contrasted variations are now manifestly no longer "spontaneous" or "indefinite", but each an intelligible further development of the ordinary contrast of more floral and more vegetative type respectively, and each carried below the essential flower organs, to their floral envelopes also, so with floral or vegetative calyx respectively; and with this contrast clearly represented in the fuller foliage of the more verdant-flowered variety. It will be found, too, as we would now expect, that the latter is the more usually pin-eyed; and vice versa for the other and doubly floral form. Similarly in passing to other orders and genera, say the common snapdragon (Antirrhinum), we at once see and understand how their "giants"—though more floral than the parent species (normally taller still)—are far surpassed in floral size, colour, and beauty by the much smaller "dwarfs". Converse observations can next be made, along a wayside, on the variations of the common plantain (*Plantago lanceolata*), and so on throughout nature and gardens alike. If so, have we not here a process of origin of varieties, and even of species and more? The palæontologists are often strong on the definiteness of variation, but this is often explained away as being possibly but the result of natural selection; and it is difficult to answer this when forms are dead and gone, and so beyond observation in the life from either viewpoint. Hence the value of such observations as the above on variations in life. And here most obviously for the more floral forms, where the variation is so manifestly from within; and where natural selection, even if aiding so far—as when there is nectar or conspicuousness to insects—also wields the shears of Fate, and cuts off the most fully floral, since less vigorously vegetative. Here is the reason why the finest flower varieties are so costly—for instance the splendid "Parrot tulips", so delicate and perishable compared with the bud-like and well-growing "Darwins". Little further observation is needed to show how large is the ovary in the highly vegetative

and bud-like Darwins, and smaller, yet still well grown, in the ordinary more open forms; but how small—often even aborted—in the Parrots. Yet notice in these how the gorgeous and fullest-opened perianth even falls back, as in the Iris withering, but here losing co-ordination before it withers. Finally, note the frequent large midribs of verdant vigour in its gaudy outer perianth leaves especially, for may not these be the expression of an incipient return of this exaggeratedly floral form to more vegetative life—much as we saw above for the common Asparagus, and for re-vegetative Orchids? If so, might it not be possible next to make experimental anti-floral cultures, and raise smaller and greener Parrots from these too splendid red ones? Let some younger gardener try it, for time would probably be required. Since the green roses we can get from any nursery are such reversions from red ones, this kindred tulip-experiment is by no means hopeless; and still less would it be absurd to cultivate these back to flowering again. Perhaps re-invigorated, both in foliage and flowering together, like Masdevallia above—and for that matter as the often at once super-verdant and highly floral composites have arisen in nature; or these by turns, like the sunflowers and Jerusalem artichokes above mentioned. If so, such plant-forms are of no mere "spontaneous" or "sporting" variations, but have progressive development from within, intelligibly rationalised in terms of its elemental rhythm, and even to a change in direction of their evolution; even to their own reversibility of rhythm in this dance of life, when this goes too far for safety. Is not this in fact another expression of the *vis medicatrix naturæ*, and this at times to the reversibility of what may well seem its extremest figures? Think here of our own human and musal dances, with their contrasted beauty of alternately preponderating urges of life-sustaining and life-continuing—and this dancing not only individual but with partners and groups, all deeply life-urged and life-inspired.

The wonderful circumnutation movement of leaves and shoots is thus but the normal bow to the elemental Sun-father: the dance itself goes on throughout organic life. Each organism is so far strictly conditioned, and subject to all the chances, advantages, or accidents of life as well; yet it is none the less also internally conditioned. First of all by hereditary tradition; yet this not preventing the development of new and varying steps: so the dance of Evolution goes on, ever the same, yet often new. In brief, life is so far plastic, so far fated, yet active and insurgent as well.

In the most fertile and variable of all old mytho-poesies, though Brahma breathes the urge of life, and Vishnu maintains it, till Siva destroys, one of its greatest imageries is yet that of the music and dance of Siva in creative mood—amid flaming energies and upon the conquered, though lately threatening, earth-dragon. So Kali, the destroyer, is also Nature-Mother in turn. To modern

Western minds, all this long seemed mere fantasy: so when thus, in her twofold shape, she appeared to Darwin, he, not knowing her old name, could but call her "Natural Selection"; and his Western readers thought her new. So, too, with Lamarck's, Schopenhauer's, and Bergson's successive renewings from the breath of Brahma: which they also could but call in their own tongues *besoin et désir*, or *Wille zum Leben*, or *élan vital*. But now, in our modern mytho-poesy of science, developing in its turn towards a corresponding cosmogony, yet now of cosmogony as evolution, we again find room and reason for all these visions of life; and why not yet more beyond? So are we not here retaining the essential values alike of the Darwinian and neo-Darwinian doctrines and of the Lamarckian and neo-Lamarckian ones; since here reaching a stage deeper, into the essential life-processes of self-maintaining and species-continuing, not only as successive, but as interacting, and even as capable of re-alternating in their rhythm? Luck-situations are not, of course, excluded; these may and do constantly arise, and with vital or mortal results: so here is no rejection of the importance of natural selection; though decidedly of its "All-sufficiency". Yet with no claim of all-sufficiency for such internal variations either, nor denial that here also there is ample scope for the varied chances of fertilisation, and for other factors so well expounded by Mendelians and neo-Mendelians: enough if the preceding scanty outline suffice to persuade open-minded representatives of each and all these schools to consider whether such cases of what we cannot but call main and definite lines and rhythms of variation have not also their substantial significance in the evolutionary process; and this sufficient to justify our further interpretations, even of Darwin's classic studies, as of primroses and orchids, of wind and insect fertilisation, of plants (and animals) under domestication, and so on for other and later Darwinian, post-Darwinian, and De Vriesian and other contributions. Each and all valuable though these are, it is of the very nature of investigation in general, and of physiology in particular, to look more fully into the protean world of variations, and see this as no mere indefinite chance-medley, but as an orderly, yet intelligibly varying, rhythm of life-dance.

Life has all the nine Muses in its very being, since these are but high aspects of its interplay of organism and environment, discerned in another of the highest moments of past evolution: so their rhythms and dances needs must range to lightest comedy and to deepest tragedy, with all other life-developments before these and between. All these are ever traceable in the movement of human life—witness alike our histories and biographies; our tales, romances, and novels; our sciences, philosophies, and wisdoms; our poesies, lyric, epic, dramatic; our creations of arts and music as well. All such are modes and moods of the human spirit; for this, albeit seem-

ing so strictly utilitarian in each of its self-sustaining beginnings, becomes increasingly spontaneous, creative, and poetic in its life-developing and life-continuing. All these are but culminant expressions of what we find in more simply organic life; and hence it is that fabulists and mythologists, poets and heralds, have ever used so many of its forms as prefiguring and illustrating our human life, sometimes to intensifying or exaggerating its activities. These old nature-students were thus more evolutionist than they knew. Only in its life-sustaining beginnings, if even then, can life seem strictly utilitarian; it is increasingly creative, literally poetic, since life-shaping. For in its race-continuing developments, which so deeply modify and advance its individuality, it becomes creatively evolutionary; so in the old and fundamental as well as higher sense, it is truly poetic; for all save degradedly utilitarian life-forms, such as the parasites, thus attain to their full beauty, of which the very incipience so often enhances that of their individual youth as well. The whole vast and complex, yet orderly and increasingly intelligible cosmogonic process thus culminates. For what is beauty? First of all in the glories of inorganic nature; then these as affording environment and scene for the yet subtler and more varied results, expressions, and indices of the innumerable perfectings of Life, in its protean Evolution. Each species and variety is thus the product of some characteristic combination of evolution-factors, both the inward and the outward; and its biography thus differs from its neighbour's. There is a particular plot in the story of each, though the great Nature Comedy includes them all. "In Nature's infinite book of mystery, we can a little read;" but it will be long before we have unravelled all these minor plots, and still longer before we can fully appreciate and worthily take part in this long Tragi-Comedy of Life, in which we short-lived mortals are each and all actors even more than spectators; preparing for our successors in their turn.

GROWTH, FORM, AND VARIATION.—Since Descartes's invaluable introduction—or rather development—of his co-ordinates, these have been of increasing use, first in mathematics, but also in cartography and in meteorology, etc., in physics, later in social statistics, whence next in biometrics. But it seems seldom adequately realised, even by those who most use such graphics for their special purposes, that they really afford a general method, very comprehensively applied throughout the range of the sciences, and of course to many arts as well, as from architectural plans, elevations, and sections as static, to the kinetic graphs of engineering processes. The mineralogist's crystal-diagrams, the chemist's graphic formulæ, or now his imageries of atomic structure, are alike thus clarified before the mind. The biologist thus helps his thinking and exposition also: witness his diagrams of the natural orders of flowering plants, or

for coral, worm, or vertebrate. That Plato's archetypes were not merely metaphysical or poetic ideas—but also owed not a little to his strong geometric interests, is a view surely supported by the rise, first of comparative anatomy and next of pure morphology, in modern times; for surely he would have rejoiced with Goethe over his understanding of the rose as essentially leafy, and his view of the skull as vertebrally segmented; for though that archetypal concept has been proved faulty, it has none the less stimulated the progress of morphology. In short, then, it needs but a little reflection to see how thoroughly the progress of the sciences is in terms of that of their graphic conceptions; thus in passing from the Ptolemaic to the Copernican system of astronomy, or with Pasteur considering the build and behaviour of dimorphic crystals of tartaric acid, or in comparing the forms of life, and their physiological changes as well. We see, too, that graphics are by no means necessarily static; but, indeed, serve kinetic uses above all. Hence that graphic imaging which so largely occupied Kelvin's deep-searching mind, since he was wont to say he could not really understand any physical concept or process until he had conceived it in working model.

In biologic studies, morphological and physiological alike, such endeavours are invaluable: thus our studies of the plant are but detailed, even dissociated, until we again bring them back into it as a whole and in life; and thus see it as a working thought-model, simultaneously exhibiting all we can learn from the special inquiries of the sub-sciences. The great advances of the past generation from simply descriptive embryography to much of rationally conceived and kinetic ontogeny, in terms of growth and functioning in detail, are obviously of this character. The long discussions of evolution, even since Darwin, show that it has been not a little difficult to do the like on the larger scale of phylogeny, i.e. for species, genera, orders, etc.: but a very valuable and far-reaching advance was made by Prof. D'Arcy Thompson in his *Growth and Form* (1917). For here he presents growth as rationalising form; a doctrine often generally stated, but now traced more clearly and comprehensively than ever before; and from cell to cell-bodies, from Protozoa to Mammalia. The forms even of hard parts, from the shells of Foraminifera to those of Molluscs, or again horns, teeth, and skeletons, are thus shown as modelled by the plastic energies of growth; and this with graphic clearness, and even frequent mathematical elucidation as well. All this well prepares and leads the reader to his final chapter, with its "Theory of transformations, or the comparison of related forms", with his most vivid graphics of all. In popular teaching to beginners in botany, we have used for illustration of the varieties and changes of leaf-forms a model leaf, cut from a thin film of elastic rubber: and still better, for complexer form-changes, the child's amusing plaything of an india-rubber face, which is so readily

lengthened and broadened, bent or even twisted, into protean changes of features and expression. Our author, however, does the like throughout wide ranges of form, and with serious, and serial, thoroughness, by drawing a simple form on a regular network of co-ordinates, and then variously modifying these: at first in the simplest possible way, by vertical lengthening or horizontal broadening, and then with further changes mathematically suggested, followed, and explained. Even in the first of such modified graphics the widely different dimensions presented by homologous parts—say the increasingly slender metacarpals and digits of ox, sheep, and giraffe—are well shown as a continuous series. He reproduces drawings of heads made by Dürer upon his own networks of co-ordinates, modified in different proportions, or even tilted obliquely, with changes of facial angle, features, and expression accordingly. Next he applies the like principle and method to express the widely contrasted aspects of allied genera of many kinds, from among crustaceans, or hydroids, to series of allied fishes, so that the most eccentric and deformed-looking types are graphically shown as but modifications of simpler forms. Different types of reptilian and avian pelvis are thus arranged in well-gradated growth-series—a matter of no small evolutionary interest. With continued development of his graphic projections, what are to ordinary sight widely different forms of mammalian skulls are brought to amazing similarity; and so at length for the comparison of the human skull with that of animals. The great point thus is that leaf, pelvis, or skull, crustacean, fish, or human face, are each varying as a whole, or at any rate are thus clearly conceivable.

Recall now the classical interpretation of organic variations, usually small and seeming spontaneous and indefinite, as for instance so clearly expressed by Wallace, with his and Darwin's explanation of structural details in terms of their assumed separate origins, as in a flower for convenient example; and next the contrasted general growth-interpretation of floral forms such as have been illustrated above. In Thompson's work, however, this general growth-interpretation of changes in details is at length more fully investigated and presented, and generally applied. The argument thus speaks for itself: but it obviously invites the comment that it is full time for the treatment, by Darwinians and neo-Darwinians alike, of the whole question of variations, in their long customary terms, to be fundamentally revised.

Thompson's treatment of growth-processes, as widely transformative, may also here with advantage be correlated with Child's suggestive investigation of metabolic gradients, since these may surely be brought into close and even complemental relation.

Neither of these theories seems as yet to take account of that rhythmic contrast, yet co-adjustment, of the processes of growth

and nutrition on one hand, with those subserving reproduction on the other, of which we have already urged the evolutionary significance and the interpretative value over so many fields, hitherto considered too separately. And it is also reciprocally evident that our presentation remains too much as it was in our earlier volumes, and so needs fuller development, with the help of the methods and results of both Thompson and Child.

It is also of the essence of all these three doctrines, that without interfering with the remarkable progress of genetic research, they return to the investigation of that variability of the organism itself, which has been so often left out of account since Weismann's concentration and insistence upon the essential reproductive elements and processes: valuable and stimulating though that has been.

Again, is it not evident from all these three variously developed viewpoints alike, that with their closely kindred and fairly comprehensive interpretations of changes in growth and form together, the long customary and detailed view of variation, so essentially mechanistic—indeed, so closely machine-like—has, largely at least, to be dispensed with? For on all three later lines of interpretation, "small variations" appear as the consequences, in details, of the general growth of the organism as a living unity. The difficulty, on mechanistic principles, of explaining the marvellous co-adaptation of variations, if arising separately and distinctly, and of this also by natural selection alone—a difficulty which Darwin indeed so candidly admitted—thus wellnigh disappears; and in favour of more continuous and comprehensive views of their origin, in course of the growth and development of the whole being.

Variations need for their survival a complex adaptation, at once in their own particular functioning and structure, and also to the organism as a whole; with its complemental adaptation to them in its turn, and with change accordingly. From the Darwinian point of view, these variations, in absence of any definite theory, remain "spontaneous and indefinite"; for though cases of "correlation of variations" have of course been considered by Darwin and later writers, these remain but empirically recorded, and without explanation. The neo-Darwinian view, with its insistence on variations as fundamentally germinal rather than somatic, has concentrated its inquiries upon the sex-elements and ovum, and there into a sort of dice-throwing among the multifarious possibilities of the chromosomes. This view of variation thus remains, indeed more than ever, on purely mechanistic and morphological lines; and it still lacks complemental physiological explanation, which should accompany it and carry it onwards into a rationale of development. Conversely, all the above three contributions to the understanding of this process have still to be coadjusted with the results of the geneticists.

Growth doctrines have once and again been suggested; even elaborately argued for; as so notably, and for very various animal groups, by eminent American palæontologists especially—Cope, Marsh, and Hyatt as conspicuous examples. Indeed, the first-named considerably elaborated his doctrine of "bathmism", as a presentment of evolutionary changes through growth. This was ridiculed at the time as but a repetition of little Topsy's account of her own antecedents ("'Spec's I growed!"): yet Goethe's view of living nature, Robert Chambers' treatment in his not uninfluential preparation for Darwin's more thorough presentment of the general evidences of evolution, and, indeed, earlier precursors also, may here be recalled. The harmonisation of theories above suggested thus needs all it can gain from those earlier ones also.

Again, while all such growth-interpretations of evolutionary change are unfavourable to the strictly mechanistic—and thus apsychic—view of their origin and correlation, they cannot but be welcomed by all the schools which are open to consider the compresence of a psychic element or aspect in the life of organisms. For on any of their views these can no longer be conceived apart from individual development and general evolution, but as in some way related to it. Yet the question of how far such relation is but epiphenomenal, and how far active, even more or less co-ordinative, obviously affords ample field for inquiry and discussion. (See Chapter XIII, The Theory of Life.)

MUTATIONS IN SNAPDRAGONS.—There are few flowers in the garden that surpass snapdragons in variety of coloration, and yet almost all the well-established cultivated races have had their origin in one natural species (*Antirrhinum majus*). It has proved itself one of the most sporting of plants, like Lamarck's Evening Primrose. Its mood is all for mutation; it is always producing something new, not only in the way of delightful soft colours, such as rose and orange, but in other characters, such as the foliage, and what one may venture to call the grimace of the flower.

Everyone has a soft heart for snapdragons, not only because they are beautiful, vigorous, frolicsome flowers, but because they never fail to reawaken a reminiscence of one of our earliest childhood experiments, when we fumblingly opened the dragon's mouth and looked down his throat, or inverted him into a munching rabbit. We did not know then that the flower keeps its mouth shut so as to protect the pollen and nectar, especially from unwelcome insect visitors. The welcome visitor is the Humble-bee, whose weight on the landing-stage is enough to open the corolla. Sometimes a biggish butterfly does the trick; and both bee and butterfly are, metaphorically speaking, welcome, since they carry the pollen from blossom to blossom, and thus bring about cross-fertilisation. Not

that this is indispensable, for self-fertilisation readily occurs, both in the garden varieties and in the wild species of snapdragon.

We get a vivid glimpse of "instinct" when we see a young Humble-bee, perhaps on its first foraging expedition, tackle a difficult flower like Antirrhinum. Only instinct would prompt a creature to try a closed door and to lean its weight against it the very first time and without any awkwardness.

Since this century began there has been an intense study of snapdragons on the part of botanists, and one of the keenest of observers and experimenters has been Prof. Erwin Baur of Berlin, who has devoted twenty years to studying variation and heredity in the common species and its relatives. There are several reasons why the snapdragon is well suited for this kind of inquiry. As we have said, it is in a mutating mood; it is at present a copious fountain of change. Moreover, it is a vigorous plant, not short-lived, not difficult to cultivate, and a single blossom may have as many as 400 seeds. And the fact that it readily self-fertilises is of considerable advantage in genetic experiments, since it removes the complication of dual parentage.

What Prof. Baur has proved is very interesting, for, as regards snapdragons, it brings us back to very orthodox Darwinism. The garden races, which are almost entirely the differentiated descendants of the wild species, are constantly exhibiting small mutations; that is to say, intrinsic germinal variations, small in amount, but crisp and brusque in character, and transmissible in their entirety in Mendelian fashion. They have nothing to do with minute modifications imprinted on the individual by some peculiarity of soil or weather; for the small mutations are intrinsic, not extrinsic, outcomes not imprints; and they are conspicuously transmissible or continuable, which one dare not say of modifications or acquired characters. The small mutations of snapdragons are expressions of germinal changes in the hereditary factors; and they are probably of the same nature as the large mutations or discontinuous variations, popularly known as sports or freaks. But they are small in amount and of very frequent occurrence.

Various evolutionists who admit the reality of mutations have been inclined to depreciate their importance, on the ground that they tended towards monstrosities and represented a weakening of germinal vigour. This may be true in some cases, such as fancy goldfishes or waltzing mice; but it is certainly not true of Baur's small mutations in snapdragons, for these are generally new departures within the limits of normality. They find expression not only in the flower and its colour but in many parts and characters of the plant. Sometimes they suggest an enhancement of vigour, as when a mutant appears with a deeper green in its leaves. In any case there is rarely any hint of the pathological in the small mutations proved

to be frequent in snapdragons. In familiar metaphor, the mutants are simply trying to go one better than their parents.

After a profound study of the garden races and wild species of snapdragons, Baur has come to the conclusion that they have been and are in many cases the result of the summation of small mutations, comparable to those that are of everyday occurrence in the garden. In natural conditions the summation may be put to the credit of natural selection, which has sifted the mutations in reference to the diverse and changeful conditions of locality and climate. This is an eminently Darwinian conclusion; for Darwin thought much more of the creeping than of the leaping of the eternal Proteus. But whereas Darwin was vague in regard to his raw material, of "small variations", Baur is very precise in regard to his "small mutations", except as regards their cause.

This investigator, who confirms Darwin's belief in the cumulative importance of little changes which we might call evolution-jerks, is far from saying that these furnish the whole of the raw material of progress. On the contrary, while he lays chief emphasis on minute changes in the hereditary "factors" or "genes", changes which occur abundantly even in "pure lines" (all descended from one parent), he admits that new departures may arise by combinations of different sets of factors in crossing different strains. But the existence of these different strains depends in snapdragons on the previous summing up of small mutations.

There are species of Rose with seven chromosomes or nuclear rods in each cell—surely a suitable number for a perfect flower! But there are five known species with 14 chromosomes, and others with 28, 35, 42, 56, and so on. In the Rose, therefore, and in some other genera, evolution has implied multiple combinations of different sets of chromosomes. Thus there are several distinct 56-chromosome—"tetraploid"—species of Rose, which have arisen through the combination of different "diploid" or 14-chromosome species. This is a very interesting mode of evolution, of which we shall hear much in years to come; but it cannot be the method observable in snapdragons, since all the species of Antirrhinum that have been studied have the same number of chromosomes, namely eight.

But what, it may be asked, of the large mutations, the "transilient variations" or freaks; do they not occur among snapdragons? Assuredly they do, Baur answers; and it is to them that the experimental gardener mainly devotes himself, making them the subject of his artificial selection. His sieve is not fine enough in its mesh, speaking metaphorically of course, for the small mutations on which the sieve of Natural Selection operates. Conversely, the sports or large mutations, which catch man's fancy and come under his ægis, tend to be eliminated by Natural Selection as too extreme. The gist of the matter is that in snapdragons the majority of the

new departures that count are small mutations which occur abundantly even in "pure lines". Thus the secret of snapdragons seems to confirm Darwinism.

SUMMARY AS REGARDS VARIATION IN PLANTS

While the fact of the origin of species by evolution is no longer disputed, nor the operation of natural selection upon organic forms any longer denied, the absence of any general theory or rationale of variation in either the animal or the vegetable world is not only generally admitted, but often regarded as inevitable or even hopeless: variation to some writers being simply "spontaneous" or "accidental"; to others, if not fortuitous, at least dependent upon causes lying as yet wholly, and perhaps hopelessly, beyond our present powers of analysis.

A theory of variation must deal alike with the origin of specific distinctions and with those vaster differences which characterise the larger groups. To commence, then, with the latter, we may pose such questions as:

1. How comes an axis to be arrested to form a flower?
2. How is the evolution of the forms of inflorescence to be accounted for?
3. How does perigyny or epigyny arise from hypogyny?
4. How is the reduction of the oophore and differentiation of the sporophore to be explained among cryptogams and phanerogams, and why should the moss type be so aberrant and so comparatively arrested?
5. How did angiosperms arise from gymnosperms?
6. How did wind-fertilised flowers arise?
7. How are the forms of fungi, algæ, etc., to be explained?

Does the explanation of such questions really lie merely in the operation of natural selection upon innumerable "accidental" variations requiring separate explanation in every case, or is any constant law of variation discoverable?

Let us note the parallelism of form exhibited in many of these cases of unrelated organisms, and inquire whether this does not give us some other clue to their origin.

In phanerogams we find the raceme modified into the umbel and the spike by arrest of the main axis or of the flower stalks respectively. Suppression of both gives the capitulum, and, as specialisation goes on, the convex flower-bearing surface of the composite becomes flattened, as in Dorstenia, and finally deeply hollowed, as in the fig. (see Fig. 162, 1–4).

In simple flowers an indefinite number of modified leaves is

arranged round the axis, whose internodes are suppressed. The first advance is to a definite number of sepals, petals, stamens, and carpels in the arrangement called hypogynous. A carrying on of the outer parts of the axis gives the perigynous position to the stamens, and the final form is the epigynous, where stamens, petals, and sepals are all carried past the ovary, the carpels occupying the inside of a pit instead of the outside of a cone (see Fig. 162).

Both these cases are clearly explicable by reference to the familiar antagonism between reproduction and vegetative growth, which may be analysed back to its basis in the constructive and destructive metabolism of protoplasm. We may view in the same light the concave form of the spore-bearing surfaces in many Fungi and Algæ—for instance, Peziza or Fucus—and even the emarginate form of the fern prothallus, where the sexual organs appear.

Note also that the shortening and reduction in the inflorescence of the Coniferæ from fir-cone to yew-"berry" is parallel to that of the phanerogams. The reduction of indefinite to the various forms of definite inflorescence is another change in the economy of the phanerogam. Similar to this is the reduction and even loss of bracts, and usually of petioles and stipules in the sepals. The complete or partial loss of the calyx and petals is usually considered degenerate; but from the present economy point of view, it seems a more complete specialisation for reproduction. In getting rid of coloured and merely attractive organs, and assuming wind fertilisation, the vegetative system is still further reduced.

The lessening in the number of stamens, carpels, and ovules in all the more evolved orders of plants is a parallel case, which the reader will readily develop. A wider consideration shows the gradual shortening of the sexual generation from the Mosses onwards through the Lycopods, Equisetaceæ, Ferns, Cycads, and Coniferæ, to the phanerogams, where it is represented by pollen grain and embryo-sac alone. The comparative failure of the moss type seems thus due to an inevitably unsuccessful attempt at vegetative life on the part of the reproductive generation.

It is seen from cases such as the above-mentioned that the reproductive axis, organ, tissue, in every case tends to become more and more shortened, depressed, or hollowed in proportion to the vegetative. In wider terms, whenever disruptive changes in the protoplasm predominate over constructive, the tendency is to produce a concave surface, as seen, for example, in the hollows of nectaries, or in the invagination of the blastosphere to form the gastrula.

This conception may be further developed, and shown to apply alike to the construction of the general genealogical tree, and, in particular, to the affinities of the flowering plants, and even frequently to the interpretation of the minute details of floral structure

usually regarded as the product of natural selection acting on "spontaneous" local variations; nor need its application be restricted to the vegetable kingdom only.

LOCALISATION OF PLANT-RESERVES.—As such localisations occur in very various situations in different plants, yet all get utilised as required, particulars of these seem of little interest from the physiological point of view; and even the morphologist has paid little beyond descriptive attention to the characteristic forms they assume, and thus practically left them within the vagueness of "indefinite variations". But in some cases, at least, we can group these in definite order; as notably among our most familiar cruciferous plants, like greens, cabbages, and turnips. For what more natural than that leafage like that of our common greens and kale, actively photosynthetic while also keeping on their growth, should be understood as first of all utilising their abundant growth-material in enlarging their own leaf-surface—and this most simply with expansion of its marginal area, where least restrained by the hardening of the woody element of the smallest fibro-vascular bundles and the toughening of their bast elements—so giving us our familiar curly kale. Where the fibro-vascular network can yield more uniformly, the whole leaf can enlarge more simply too, as in our ordinary cabbage; but if it early becomes more resistant, the growing leaf parenchyma cannot but bulge upwards, even with more or less wrinkling, as seen in varieties of the savoy cabbage; while in sea-kale it is evidently the region of the mid-rib and leaf-stalk which yields most readily to parenchymal growth and storage. As the outer (i.e. basal) leaves of our common cabbage reach maturity, see how they more and more contribute to the magnitude of the younger apex-ward leaves, which they successively cover and enclose, so producing the immense yet simple bud-form so characteristic of the cabbage. A kindred, yet distinct phase and form appears when the leaf-surplus goes to nourish, accelerate, and enlarge the leaf-buds, as in Brussels sprouts; and yet a further when it is carried on into the inflorescence, as in cauliflower. In Jersey cabbage the surplus largely descends towards lengthening the stem, so there giving us no appreciable store; but in the turnip the store is laid up abundantly in the extending parenchyma at origin of stem and root, and as reserve for biennial life with flowering and seeding; but which, when appropriated by us at close of its first season's growth, has yielded the most important revolution in stock-keeping since the ancient invention of hay, since for cattle-keeping over winter altogether the most profitable in history. The like transition in utilisation of reserves leads from the exuberantly leafy artichoke to its near garden ally, the midrib-succulent cardoon; while in the artichoke that enlargement and storing of reserves in the broadened

apex of inflorescence, which is not uncommon in composites, attains a magnitude and succulence which gives this its main culinary value, associated as this is, too, with kindred storage in the sheathing bract-bases.

In the common sunflower the exuberant vegetation-surplus not only goes to magnificent flowering, but affords seed-stores so large as to become of economic value in various regions; yet in the common and closely allied "Jerusalem artichoke" (not artichoke, and simply gira-sole) we have the extreme contrast of long-delayed and comparatively insignificant flowering; since the ample leaf-surplus is here conveyed to subterranean stem-tubers, analogous to potatoes alike in general form and uses, to plant or man alike.

Such instances might be multiplied; but enough to indicate how variations, at first sight seeming "indefinite", may be rationalised as phases and forms of a serial development.

But our outline of a theory must end by recognising how close to human life the problem is. Man's knowledge of the universe, of course, depends upon the country he has had to inhabit; but few are at once so securely favoured by isolation, and hence so simply intelligible, as Egypt. The very first of all the necessities of life is not even food, still less clothing, nor yet night-shelter: it is water to drink; for without this we die, in three days commonly, and with extremest suffering. Lakes are few, springs too often unreliable: hence proximity to rivers, large or small, or to an enduring well, is the main environmental condition of human existence, be this settled or wandering.

So, too, plant-life is necessarily most flourishing in soil best watered; hence richest in fruit or seeds to be gathered, in buds to be picked, and roots more easily howked up from moist soil than on the drier and harder upland. As the plant spreads and sinks its roots for water-supplies, its shoots must also grow tall and strong, were it but to nourish these. And so conversely, the larger and deeper the growth of the root system, the taller the stem, the greater the branching or leaf-wealth such roots can water, and hold firm against winds as well. So arises the broad distribution of plants, still easily observed along and across our valley sections, despite man's interferences—that of herbs preponderant by the water's edge, willows and poplars a little behind, and trees rising along the slopes above. The herbs, of course, are ever working their way uphill; and there are shrubs and even trees which come down to the water edge, and sometimes with submerged roots, like many willows and alders: still in the main, the form of our plant landscape is determined as above. And as each type of growth is ever pressing to extend its area, their struggle is ever varying the landscape in detail. Moist conditions obviously favour growth, and drier accele-

rate flowering; so here may well be a stimulus of variation, and that cumulative, towards the more vegetative or more floral types so frequent in many species and even in allied genera.

ILLUSTRATION OF A METHOD OF ORGANIC EVOLUTION

CHANGE OF FUNCTION.—Part of what may be called the *method* of organic evolution is the differentiation of some new structure out of an older and more generalised structure, of different function. This may come about in various ways; a secondary function of the old structure may become the dominant function, as when a swim-bladder becomes a lung, or vice versa; or a structure may change in the time of its development, as when the amphibian cloacal bladder becomes a reptilian fœtal membrane; or when one of a set of similar appendages, so abundantly represented that a pair can be dispensed with, varies in a manner that makes a new use possible, as when a crustacean swimmeret becomes a male reproductive appendage. There are other possible ways in which a change of function may be interpreted, but it will be profitable to take the facts first, and their theory later.

(1) The Eustachian tube, present from Amphibians to Mammals, is a continuation of the outer ear passage to the back of the mouth. In development it arises from the visceral cleft that lies between the first two visceral arches, the mandibular and the hyoid. The distal part of the cleft dilates to form the tympanic cavity, across which the drum of the ear is stretched, and the proximal part becomes the Eustachian tube leading into the pharynx. There can be no doubt that the Eustachian tube, which has no connection with respiration, answers to part of the hyomandibular gill-cleft in fishes—the one which is known as the spiracle in skate and shark, and allows of the entrance of the water used in breathing. It includes in cartilaginous fishes, such as the two mentioned, a minute vestigial gill. With the transition from water to dry land, and the associated replacement of gills by lungs, the gill-clefts lost their primary function. In Reptiles, Birds, and Mammals they practically disappear except as embryonic vestiges; but the first one persists as the Eustachian tube. That is to say, a respiratory cleft, the first of a dwindling series, finds a new utility, so persists and develops accordingly. The five points are: (*a*) the disappearance of an old function; (*b*) the dwindling of the structures concerned; (*c*) the appearance of a new function associated with new organs (lungs); (*d*) the ancillary utilisation of one of the old dwindling structures, persisting by organic momentum in embryonic life, and (*e*) its persistence in the adult.

(2) Somewhat simpler is the viper's poison-apparatus. The

venom gland seems a novel structure with startling lethal power, but what is it but a specialised salivary gland? It is usually regarded as the upper labial gland, but some anatomists call it the parotid. It has arisen by the specialisation of the ordinary type of salivary gland; the secretion has become virulent; and it has come to be enclosed in a strong fibrous sheath which is associated with powerful muscles so that the poison is driven forward with great force to the base of the fang.

And as to the fangs, each is simply a tooth folded on itself during

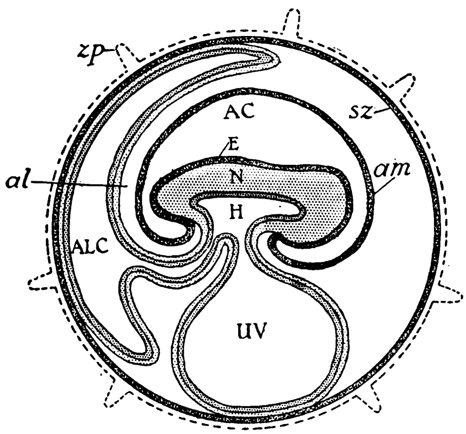


FIG. 164.

Fœtal Membranes of a Mammal. After Turner. *zp*, external ectodermic layer with processes which effect preliminary attachment of the embryo to the wall of the uterus; *sz*, the subzonal membrane, formed from the union of the outer parts of the double amniotic folds; *am*, the amnion proper; AC, the amniotic cavity containing fluid; E, the ectoderm of the embryo; N, the mesoderm of the embryo; H, the endoderm of the embryo, lining the archenteron or primitive gut; UV, the umbilical vesicle or yolkless yolk-sac, opening into the archenteron; ALC, the allantoic cavity, lined with endoderm, enveloped in mesoderm; *al*, the inner wall of the allantois, which spreads in the space between the subzonal membrane and the amnion proper. The embryonic part of the placenta, which binds the embryo to the wall of the uterus, is formed by an intricate union of allantois and subzonal membrane.

early development, so that there is formed a groove or even a complete canal, down which the poison passes to be injected into the wound. In this case, though poison-gland and fang are both distinct novelties, the transformation raises no great difficulty, for glands and teeth are both very variable. Even the milk-glands of Mammals are but highly specialised integumentary glands.

(3) There is greater difficulty in the case of the allantois, which forms a fœtal membrane (respiratory, excretory, and nutritive) around the embryo of Reptiles and Birds, and part of the placenta in Mammals. It arises as a pocket from the under surface of the gut, near its hind end, and it is the homologue of the cloacal bladder of

Amphibia, which seems to have very little functional importance and has no direct connection with the kidneys. In Amphibians, then, the future allantois is an adult, not an embryonic organ; in higher Vertebrates the reverse is on the whole true, though the stalk of the allantois seems to become the permanent urinary bladder. Another great change is that the allantois in higher Vertebrates (Amniota) is a very vascular organ, which is far from being the case in Amphibians. In this case, then, there is (*a*) a change in function and in minute structure; (*b*) a shunting of the major functional importance from the adult in one group to the embryonic life and use in higher ones; and (*c*) the preservation of a part of this embryonic structure which becomes utilised in Mammals and most Reptiles to form a new adult organ, the urinary bladder.

(4) Another striking illustration of function-change is afforded by the three linked ear-ossicles of mammals, which convey vibrations

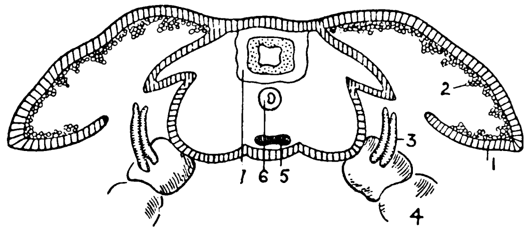


FIG. 165.

A Section through the Thorax Region of the Robber Crab (*Birgus latro*). After Semper. 1, overlap of the cephalothorax shield; 2, respiratory tufts; 3, two small gills; 4, base of a leg; 5, the ventral nerve cord; 6, the food-canal in section; 7, the pericardium around the heart.

from the drum to the internal auditory organ. Their names, from without inwards, are malleus or "hammer", incus or "anvil", and stapes or "stirrup", the first abutting on the tympanum, and the third fitting into the fenestra ovalis of the inner ear. In Birds, Reptiles, and Amphibians, their place is taken by a single rod, the columella; in Fishes there is no drum, and therefore there are no such ear-ossicles, the calcareous masses, called otoliths, being much simpler in nature and origin. But it is possible, from the development of the mammalian ossicles, to argue back to their homologies in the other Vertebrates, including fishes; and the generally accepted conclusion is that the malleus corresponds to the *articular* bone of the lower jaw in the other Vertebrates; the incus to the *quadrate*, the jaw-hinge bone in Birds, Reptiles, and Bony Fishes; and the stapes probably to the upper end of the hyoid arch, represented, for instance, by the hyo-mandibular of the haddock. Even if subsequent investigation should necessitate some modification of these homologies, it will not affect the general argument that the delicate chain

of three links between drum and hearing ear can be traced back to the sturdy hinge-work of the jaw in fishes. It should be kept in mind that the lower jaw of mammals has become a single bone on each side—evolution by simplification—and that it articulates directly on the skull with the squamosal, not with the intermediary quadrate, as in Birds and Reptiles. This change has set a number of hinge-bones free; and the interesting point is that in their function-change they have become very small and yet highly specialised. They have been utilised for a more delicate function, and this is reflected in the nicety of their structure. Here, again, we find an illustration of what seems to have been a frequent method in evolutionary change. Structures fall into desuetude and dwindle; but instead of becoming vestigial, they are often reinstated in service with new functions.

(5) On a different line is the origin of a novel structure by the exaggeration of part of an old one. The trunk of the elephant, with its extraordinary muscularity and tactility, is one of the clearest of instances; for what is it but a great exaggeration of the nose and of a portion of the upper lip? We see hints of the beginning of a similar proboscis in the tapir and in the little aquatic insectivore, the desman, which used to occur in England. Moreover, from the unusually complete series of forms ancestral to the modern elephant, we know that the trunk, as testified to by features in the fossilised skulls, was the outcome of a gradual change extending over millions of years.

(6) The spinnerets of spiders are transformations of the two last pairs of appendages on the abdomen of the embryo, while the four pairs in front of them simply disappear. The strange comb-like sensory structures projecting on the under side of the third segment of the scorpion's abdomen are the transformed third pair of abdominal appendages, and the second pair, much reduced, form the genital operculum.

The "poisers" (halteres) of two-winged flies or Diptera, easily observed in daddy-long-legs and blue-bottle, are two rapidly quivering sensory structures, somewhat like the head end of small pins. They are present in almost all Diptera, though rarely present in wingless forms; and they are not known outside the Diptera except in the male Coccid insects. It would be difficult to find more characteristic structures, and they are very intricate. Four muscles enter the base and keep up a very rapid vibration of the "halter". They are rich in nerve-endings and they have a somewhat ear-like (chordotonal) structure at their base. Their precise function is still obscure, but they are undoubtedly sense-organs. Now there seems no doubt from their position and development that they represent transformations of the second pair of wings, so normal in other orders of insects. Their place is never taken by wings in Diptera,

and no transitions are known between them and wings, yet their evolutionary origin seems certain.

Variations in the degree of development that wings attain are not uncommon among insects; the facts suggest that the restriction of the actual flying function to the *second* pair of wings has occurred repeatedly, as in beetles, though the first pair may persist as useful wing-covers. Many cases of secondary winglessness are known, as in fleas, in contrast to the primary winglessness of the old-fashioned Spring-tails (Collembola) and Bristle-tails (Thysanura), in regard to which there is no evidence that they ever had wings. We suppose, then, that the extraordinarily perfect functioning of the fore-wings in Diptera (sometimes striking the air two hundred times in a second) made the hind-wings unnecessary as organs of flight. Variations of a retrogressive character set in, and were rather advantageous than otherwise; but when the reduction had gone far, a rehabilitation of mobility and an acquirement of new sensitiveness came about, and so "poisers" evolved.

(7) An instructive instance is afforded by the gill-filaments of the tube-inhabiting Serpulid worms. On the head there are numerous gill-filaments, which are exaggerations of the tactile "palps" of many other Polychæt worms. They form a beautiful crown projecting at the mouth of the calcareous tube and completely retractile when the worm draws in its head. Now in many genera of Serpulids the dorsalmost gill-filament, on one side or on both, is dilated at its end into a club, sometimes horny, sometimes calcareous, sometimes both, which closes the mouth of the tube when retraction takes place. This stopper or operculum is very well seen in the common Serpula, whose twisted tubes are often fixed to stones in inshore waters. But in the tiny Spirorbis, which forms for itself a flat spiral tube of lime on Fucus and on shells, the distal end of the operculum is enlarged to form a brood-pouch for the eggs. In the Filigree worm (Filigrana) the operculum is but slightly developed; in Protula and Salmacina there is none. Thus we have a very interesting series, of which Spirorbis is the climax.

ATAVISM AND REVERSION

The term "atavism" is commonly used in three senses: (1) It is used to denote the hereditary reappearance of a character not seen in the parents, or even in the immediate ancestry, but found in an ancestral race, or in one related thereto. Thus markedly projecting canine teeth in man have been regarded as re-expressions of a Simian character, and supplementary mammæ on the breast of a woman have been regarded (probably quite erroneously) as atavistic

reappearances of a feature seen in some of the Lemuroids or Half-Monkeys. Similarly, extreme hairiness in man has been interpreted as an atavism, but the interpretation may be erroneous. Hypertrichosis, as it is called, may be a novel plus-mutation.

(2) The term "atavism" is used to denote the hereditary reappearance of a character not seen in the parents, but known to have occurred in a definite ancestor belonging to the stock. Thus a child may have the peculiar hazel eyes or a peculiar lock of hair characteristic of a great-grandparent, and not expressed in the intervening lineage. To such cases the term "reversion" is often restricted. Thus in his *Grammar of Science* (1900) Karl Pearson calls *reversion* "the full reappearance in an individual of a character which is recorded to have occurred in a *definite* ancestor of the same race", while "atavism" is restricted to "a return of an individual to a character not typical of the race at all, but found in allied races supposed to be related to the evolutionary ancestry of the given race". This would be a useful distinction between atavism and reversion, but unfortunately some scientific writers have used the two terms in the very opposite way, applying "reversion" to (1) and "atavism" to (2).

(3) It remains justifiable to use "atavism" and "reversion" as synonyms denoting the hereditary reappearance of characters which were latent in the parents at least, but which were expressed in definite—not problematical—ancestors, near or remote. It need hardly be said that an atavism is not necessarily a deterioration, it may be a throw-back to a higher degree of differentiation. That depends on the direction in which the species or stock is evolving in relation to its ancestors.

EXAMPLES.—A dovecot with carefully bred pigeons was left to itself for some years, after which it was found to contain numerous blue pigeons, resembling in many ways the wild rock-dove (*Columba livia*), believed to be the ancestor of all the domestic breeds of pigeon. In exact experiment this reversion to the rock-dove type has been repeatedly observed. Cultivated flowers and vegetables, such as pansies and cabbages, sometimes produce forms hardly distinguishable from their wild progenitors. The nectarine, which is derived from a peach, may produce what is practically a peach again; the white flowering-currant, which is derived from the common red form, may have branches with red flowers. In a hornless breed of cattle, derived originally from a horned breed, a horned individual may suddenly reappear. A dark bantam hen, crossed with an Indian Game Dorking cock, produced amongst others a cockerel almost identical with a jungle fowl (*Gallus bankiva*), i.e. with the original wild stock (Cossar Ewart). Similarly, in his horse-zebra hybridizations, Prof. Cossar Ewart obtained forms whose stripings were at least plausibly interpreted as reversions to an

extremely old type of horse, such as is hinted at in the striped ponies of Tibet.

There is no doubt that organisms often show peculiarities which their parents did not possess, but which their ancestors possessed. Summing up such cases *descriptively*, we may say that they seem to illustrate atavism, but the use of the term *as an interpretation* is not justified unless we can give some reasons for believing that the resemblance to an ancestor is due to the rehabilitation of latent items in the inheritance. To do this we have to try to eliminate other interpretations, and that is often difficult. (*a*) What looks like an ancient feature may be due to an arrest of development through lack of appropriate nutrition. (*b*) Similar conditions of life, e.g. of food and climate, may induce an acquired or modificational resemblance between the organism and its great-grandparent, but this would not be an atavism. (*c*) Many organisms normally show certain "vestigial organs", and these are often variable. A quantitative variation in a normally present vestigial organ is not what is meant by an atavism. (*d*) It is conceivable that an independent individual variation may happen to coincide with one that occurred generations before, but this is different from the reawakening of a latent item in the inheritance. (*e*) Filial regression, or an approximation towards the mean of the stock, is of everyday occurrence in blended inheritance, and must be kept quite distinct from reversion or atavism. (*f*) The list of alleged atavisms must also be reduced by the subtraction of well-known Mendelian phenomena. In certain cases, such as peas and mice, the crossing of two sharply contrasted pure-bred parents results in hybrid offspring which are all like one of the two parents as regards the contrasted characters; when these hybrid offspring are inbred their progeny resemble in definite proportions the two grandparents.

The fact seems to be that many phenomena have been labelled atavisms which admit of other interpretations, and that genuine atavisms are rather rare. Let us repeat that an atavism is a harking back to a more or less remote ancestor, the harking back being due to the reassertion or reawakening of ancestral contributions which have lain for several generations latent or unexpressed.

It seems unnecessary to use the term "atavism" for the common phenomenon of resemblance to a grandparent. There is every reason to believe that an individual inheritance is like a mosaic, built up of many contributions, through the two parents, from the grandparents, great-grandparents, and so on. It is a normal and frequent fact of inheritance that an offspring exhibits a peculiarity known to have occurred in one of the grandparents but not in either of the parents. There seems little utility in calling this very frequent "skipping a generation" an atavism, though it is of the same general nature, and though it is obviously difficult to decide where to draw

the line. For how long must a character have been absent or latent before its reassertion or reawakening is to be called an atavism? A drone-bee arises from an unfertilised egg, it has a mother and two grandparents, but no father. But it seems rather absurd to call its resemblance to its grandfather atavistic or reversionary. This is a *reductio ad absurdum*, for the drone-bee would resemble its father if it had one! The case may serve to show that it is undesirable to use the term "atavism" unless the throw-back is to an ancestor more than two generations antecedent.

The exact study of atavistic phenomena must have regard to characters which can be definitely measured and registered, and only when this study has reached secure results will it be possible to discuss with precision what may be called psychical atavisms, that is to say, reawakenings, often more fitly termed recrudescences, of ancestral traits which have lain latent, it may be, for generations. The garden of a shepherd's cottage which was swallowed up in a deer forest lost all trace of its previous cultivation, and became a weed-ground. After many years, under more humane conditions, it was re-delved, and there sprang up many different kinds of old-fashioned flowers whose seeds had lain dormant for several generations. So may ancient flowers and weeds now and again reappear out of latency in that garden which we call our inheritance. They illustrate atavism or reversion.

THE PULSE OF EVOLUTION

The very suggestive phrase "pulse of life" has been used almost technically by Lull, the distinguished palæontologist of Yale, to denote the occurrence of "big lifts" in Organic Evolution, followed by periods which could not be called eventful. And besides the big lifts there have been downward plunges, when great races of animals passed into extinction. There have been crises in organic evolution, such as the great advance of the fore-brain in the monkeyish animals that became arboreal in the Eocene Period, or the emergence of birds from Dinosaurian ancestors in the Jurassic Period or earlier. No doubt it is difficult to be quite sure when the various great Vertebrate initiatives were made: and as for Invertebrates we can hardly tell at all, since there are representative fossils of most of the chief groups of backboneless animals in Cambrian rocks. But it will be admitted by all that in certain periods there was a very marked advance of certain forms of life. The problem is how far these upward movements express some propitious conditions of climate and the rest of the physical environment, and how far they may also express an internal momentum in evolution.

Lull's thesis is the able development of an old but hitherto insufficiently clear idea—at first even creationist, as with Cuvier—that the great advances and retrogressions may be correlated with geologically demonstrable changes in the physical environment—in climate and in continental elevations in particular. To take the simplest case, it is plain that the setting in of an Ice Age—which has happened over and over again in the course of the earth's history—would involve severe sifting, and on the whole, it would seem, retardation. "As the physician, by a clever device, can record graphically the pulsations in the blood stream which are synchronous with the throbbing of the human heart, so I have drawn a curve to show the correspondence between the pulse of life and the heavings of the earth's broad breast." This is a thesis of great interest; so we outline a few of Lull's illustrations; and may then add a note on the probability of there being internal factors which co-operate with the undeniable external factors in determining the pulse of organic evolution. In regard to the illustrations, it may be that some remain dubious; but that will not affect the validity of the general idea that "the expression-points of evolution are almost invariably coincident with some great geologic change".

Each of the great colonisations of the dry land by animals from the waters has been a momentous event in organic evolution. The Worm invasion led on to soil-making; the air-breathing Arthropod invasion led on to the linkage between insects and flowers; the Vertebrate invasion by adventurous fishes led on, through Amphibians, to Reptiles, and thence to Birds and Mammals. In the great majority of cases the path of the invaders or colonists was from rivers and lakes, swamps and marshes, on to dry land, though the starting-point may usually have been the sea. Now it seems reasonable to suppose with Lull that the external impelling cause of the vertebrate emergence, which led through lung-fishes to Amphibians, was aridity. "Diastrophic movement during the Silurian Period initiated a widespread aridity which culminated in the latter part of the period, continued with varying intensity into and through Devonian time, and rose again to greater severity in the latter part of that period." Rivers and lakes would shrink, and there would be uncomfortable crowding in the pools; some types, like the African mudfish, would save themselves by sinking into quiescence during the dry season; others would creep ashore and learn in various ways to breathe dry air; many, of course, would be eliminated. Drought is often a drag on life, for one cannot forget that more than eighty per cent. of living matter is water; yet indirectly it may be a spur, by prompting to such achievements as getting on to dry land and learning to breathe by the internal surfaces of lungs.

But oscillations and alternations seem to have been very characteristic of the history of climates; and in part of the Carboniferous

Period there was great humidity and much low-lying swampy ground. These conditions favoured luxuriant vegetation: witness the growth of the great cryptogamic forests associated with the coal measures. Naturally enough this was a period during which Amphibians had their Golden Age; there was considerable diversity of structure, and some types attained large size. If ever there was a pulse in evolution, it was surely among these primeval Amphibians, signalised by many new acquisitions, such as fingers and toes, lungs and posterior nostrils, a mobile tongue and probably a voice.

Similarly one might suggest that humid conditions during part of the Jurassic Period led some of the big reptiles to give up hunting and take to vegetarianism, thus becoming large of size and slow in pace. Many of them sank gradually to extinction. But this state of affairs may be contrasted with the conditions of aridity and steppe-country which led at a later time to the emergence of birds. The first known fossil bird, Archæopteryx from the Upper Jurassic, cannot have been by any means the actually first creature to deserve being called avian; and one can picture its ancestors evolving from a Pseudosuchian or Dinosaurian reptile stock, adapted to swift movement on dry ground, and to flying leaps into the shelter of scrub-like bushes which grew sparsely on the bare tracts of an unfriendly steppe-land.

Perhaps it was a time of dry cold in the Triassic Period that prompted some Dinosaurs to acquire habits of great activity and an intense metabolism, to exchange scales for a non-conducting garment of fur, and to effect an improvement in the linkages of nerve and muscle and gland that led to the great acquisition of warm-bloodedness, which means being able to keep up a uniform body-temperature, day and night, year in, year out. In a word, aridity prompted the evolution of mammals.

At another time, however, when the conditions of climate and surface-relief were different, there was a luxuriant vegetation of juicy herbs and fruit-bearing trees, which would prompt another kind of evolution, leading to browsing herds and to a wealth of resident birds. Obviously one must not be content to say "aridity did this" and "humidity did that"; one must become familiar with the details now accumulating in regard to the history of climates, as in Brooks's remarkable book *Climate Through the Ages*; and one must then try to correlate particular climatic peculiarities with particular uplifts and depressions in organic evolution.

But what of the other side—the pulse from within the organism? It is well known that a particular tendency in an individual may become cumulative and acquire organic momentum, as in the case of muscle-forming or of fattening. A degenerative or disintegrative change, apart from microbes, may also spread in the body and gain in malign potency. So it may also be in racial evolution, that a

variation in a particular direction may become cumulative, and may be progressive in the sense that it increases from generation to generation. This might be accounted for by the transmission of acquired characters, but the possibility of this has not been convincingly demonstrated. It might also be due to the pairing of individuals possessing the same characteristic in a marked degree. Yet it may perhaps be due simply to what we must call, for lack of a better term, evolutionary momentum. And in this, as elsewhere, "we may have too much of a good thing". Thus progressive variation in a surely somewhat unprofitable direction has led to the male narwhal's enormous six-foot-long incisor tooth, or to the over-weighting of the Giant Irish Deer with enormous antlers; or to the over-thickening of the bony ramparts of the extinct Ground Sloth. Apart from cases where there is good reason to postulate a long-continued process of stringent selection, there is considerable evidence of an organic momentum increasing from generation to generation, and sometimes even to becoming fatal. Moreover, when a structure, slowly evolving for ages, attained to a new utility, there would also be an internal pulse. Thus there must have been an evolutionary pulse in the life of every type whose eye passed from being a light-and-shade organ to be image-forming, or whose ear passed from being a balancing organ to function as a hearing ear. The progressive variation which led to the establishment of the neo-pallium in the fore-brain of certain mammalian types must have meant an evolutionary pulse, and the same must be said of every advance that gave its possessors in some appreciable degree a new world. We must thus later consider more carefully what such evolutionary pulses may be.

WHAT ARE GENES?

What Galton called "the natural inheritance", inconceivably condensed, is carried by the egg-cells and the sperm-cells, and though it would be rash to conclude that the cell-substance does not carry some of the old-established items in the inheritance, the evidence is strong that the nuclei of the germ-cells are the chief vehicles of the hereditary characters which persist from generation to generation. But in certain conditions the complex, readily stainable, chromatin material of the nucleus of the germ-cell takes the form of well-defined chromosomes; and it is a widely accepted view that the chromosomes are the vehicles of the hereditary characters. Fixed and stained, the chromosomes often look so extraordinarily well-defined that we are apt to forget that in their living state they seem to be differentiations of fluid, surrounded by a film. Yet we know that each species has its own particular number of chromo-

somes, and that each chromosome is split up the middle longitudinally in every typical cell-division, so that each daughter cell receives a longitudinal half of each chromosome. In the fertilisation of an egg-cell by a sperm-cell, analogous chromosomes of maternal and paternal origin are closely apposed in pairs; and when the fertilised egg-cell divides into two, each daughter-cell receives the normal number of chromosomes, half maternal, half paternal in origin. In this respect, as Huxley said long ago, the web of the future organism has its warp and woof intimately maternal and paternal, though it

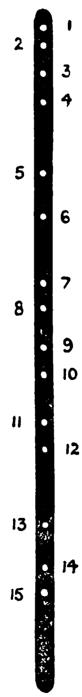


FIG. 166.

Diagram of the Position of the Hereditary Factors or Genes on a Chromosome of the Fruit-fly (Drosophila). After Morgan. The figures 1–15 indicate the position of as many different genes.

does not by any means follow that each thread will find equal expression in development.

But what are *genes*? The last long answer to this question is to be found in Prof. T. H. Morgan's Silliman Lectures, *The Theory of the Gene* (1926), a volume of over three hundred pages. Genes or hereditary "factors" are paired elements lying in linked groups in the germinal material. In all probability, they normally lie in a paired linear order in the chromosomes. They are the germinal representatives or initiatives of the heritable characters of the future organism; but one gene may affect several characters, and one character may require the co-operation of many genes. When

the germ-cells undergo the process of maturation, the members of each pair of genes separate; and the result is that each of the resulting germ-cells has only one of each pair of genes, some having the

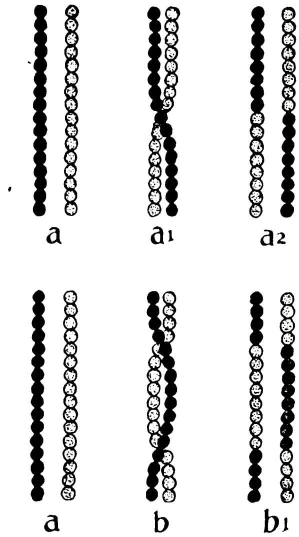


FIG. 167.

The Chromosomes of the Germ-Cells become closely associated in pairs, a "synaptic" apposition, as in *a*. They are living structures and may move crosswise on one another, and in different ways, as suggested in *a*1 as compared with *b*. Part of the one chromosome may cross over into the other. But when the members of a synaptic pair become definitely separate again, the results may be different in different cases, as is suggested by the contrast between *a*2 and *b*1. This is one of the ways in which variations may arise. After Morgan.

one and some the other. In the subsequent fertilisation, there is an assortment of the genes, so that a fertilised egg-cell may have two of the same type or two of different types. Yet it must be noticed

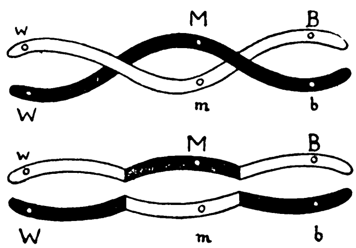


FIG. 168.

A More Complex "Crossing Over" Process in which two interchanges have occurred. After Morgan.

that the assortment of the genes is not as if they were so many glass balls of different patterns and of two different colours, for the genes are held in definite linkage-groups.

An opportunity for new permutations and combinations is afforded (*a*) in the reduction-division that occurs in the maturation of the germ-cells, and (*b*) in the reassortment that takes place in fertilisation. But (*c*) there is strong evidence in support of the view that there may be "crossing-over" or interchange between the groups of paired elements or genes, as if they were arranged in double file and a number on the right exchanged position with a corresponding number on the left. Thus, as regards all kinds of novelty or new departure that can be accounted for in terms of new permutations and combinations of representative hereditary factors or genes, we know more than Darwin did, who, with his characteristic frankness, confessed that his ignorance of the causes of variation was immense. But the probability is that, apart from the shuffling of the cards, there may be from time to time an intrinsic change in the nature of the gene itself. If so, that remains one of the central secrets of life.

THE BIOLOGICAL THEORY OF NURTURE

Horoscopes are not much in fashion nowadays, except among the highly imaginative or the undisciplined; but the problem is always with us as we look at a babe: What manner of person lies there, in possibility? How far is the final result already fixed, how far is the outcome an open question? Is life in some measure an unpredictable adventure?

What are the factors or influences that determine the shaping of an organism and its life? Man's case is in some measure peculiar, since he is, more or less, a rational, social person, ζῷον πολιτικὸν, as Aristotle puts it; and super-organic influences, such as social tradition, play upon him potently; but, biologically considered, all living creatures are subject to the same laws. For all alike there are, *sub specie vitæ*, three biological "Factors"—Heredity, Function, and Environment. The influence of function and environment is technically called "Nurture" in contrast to what is implied in the inherited "Nature".

The first Factor is *Heredity*—which means the relation of genetic continuity between successive generations. The natural inheritance includes all that the living creature is or has to start with in virtue of its hereditary relation. "Bless not thyself", said Sir Thomas Browne, "that thou wert born in Athens; but, among thy multiplied acknowledgments, lift up one hand to heaven that thou wert born of honest parents, that modesty, humility, and veracity lay in the same egg, and came into the world with thee." "A man", as Heine said, "cannot be too careful in the selection of his parents."

Heredity, the past living on in the present, is the first Factor, and the greatest of the three.

The second Factor is *Environment*—all manner of surrounding influences that play upon the living creature, making deep dints or giving light touches, awakening some buds and frost-biting others, encouraging and depressing, training and thwarting. Environment is the second factor, and some of us think that it comes a better second than others of us will allow.

The third Factor is *Function*—what the creature does or does not do, the influence of use and disuse, or work and play, of exercise and rest. When we consult a book like Arlidge's *Diseases of Occupations*—a grim curiosity for future ages—we realise what an important factor function may be for evil as well as good in the individual life. The importance of function as a life-shaping factor is expressed in various wise sayings: "By force of forging one becomes a forgesmith." "What you have inherited from your ancestors you must use if it is to be your very own." In the language of the immortal parable, we must trade with our talents.

Before giving illustrations of the three great factors, one may be tempted to ask if there are not four. A swallow born and bred in Britain flies south at the end of summer, and the Aberdeen University Bird Migration Inquiry has helped to prove that such a swallow may return the following spring to the very farm-steading, and nest, of its birth and youth—a wonderful homing. That it can make the double journey successfully depends mainly on its inheritance, but partly on its functioning, its early training in flight, and partly on environment, as from the nutrition which gives it strength to fly to the stimuli which pull the trigger of the migratory instinct. But is there not also a cosmic factor—of old called Fate, by some called Chance, or, again, Nature or Circumstance, quite uncontrollable by the creature itself and careless of it, which offers or withholds opportunities, which meets some migrants with a fatal storm and offers others a fair haven? Is not one of the factors in our own life a giving or withholding of opportunities which we, at any rate, have nothing to do with, which we call providence when it is with us, and chance when it is against us? But, perhaps, this may be included as part of our environment. Indiscriminate Selection has to be recognised—as from earthquake to change of weather.

ESTIMATE OF NURTURAL INFLUENCE.—The modern idea of the biological controllability of life, surely dating from Darwin and Pasteur, led, not unnaturally, to an indulgence in over-sanguine hopes as to the ameliorative influences of function and environment. This was held to be demonstrable for the individual, and before the days of Galton's and Weismann's wholesome scepticism as to the transmission of bodily modifications or individually acquired

characters, it was often held to be true as regards the race. But a strong reaction has set in. Let us briefly consider why.

(1) If we take the eggs of, say, the blackheaded gull, and hatch them in an incubator in the laboratory, and rear the results in confinement, we get, as everyone knows, a number of normal, well-endowed young birds, which will migrate months afterwards when their kinsfolk fly about overhead. The environment, the whole nurture, was in this case very peculiar, but it did not seem to make much difference. There is evidence, indeed, that birds which have not known freedom are badly handicapped when liberated, because they do not know their way about. But the clear fact seems to be that for many creatures changes of nurture do not fundamentally matter as long as the essential conditions of life are not interfered with. The full inheritance may not be expressed, but a large proportion of it is realised as usual. There are many delicate creatures, such as the larvæ of sea-urchins, which are difficult to rear, which do not readily stand even slight nurtural changes; but many other creatures can within limits adjust themselves to, and develop normally in, quite peculiar conditions of life. It is a very striking fact that the ovum of a rabbit can develop for two days normally outside of the body; and Man is peculiarly master of his Fate. What, then, is the importance of nurture?

(2) It is likewise a familiar fact that there is often an extraordinary tenacity in the persistence of hereditary characters, no matter how the nurture is changed. Having all the fingers thumbs has been known to persist for six generations, night-blindness in a lineage for two and a half centuries, a particular kind of dwarf for four generations. A peculiar variety of the Greater Celandine with cut-up leaves which appeared suddenly in an apothecary's garden at the end of the sixteenth century has bred true ever since. "He that will to Cupar maun to Cupar", we sadly say in Scotland. "Each man's nature is his fate", said Democritus, and the modern students of heredity agree. What, then, is the importance of nurture?

(3) Another consideration is this. It is not difficult to impose peculiarities on organisms by subjecting them to peculiarities of nurture. A goldfish kept continuously in the dark becomes quite blind; caterpillars subjected to cold may turn into dark-coloured butterflies; some birds, such as the bobolink, may be dieted so that they keep their breeding plumage through the year and will sing their spring song in mid-winter. These are three instances out of hundreds of the power of nurture, to which we shall return. But, as things stand, we cannot assert that any one of these extrinsic modifications is as such, or in any representative degree, entailed on the next generation. So what is the importance of nurture?

(4) We have the statistical evidence furnished by Karl Pearson

and his workers in the Galton Laboratory—which leads them to the important conclusion that the results of changes in nurture are of relatively small importance compared with the results of variation in the physique, the mentality and the habits of parents—that "the degree of dependence of the child on the characters of its parentage is ten times as intense as its degree of dependence on the character

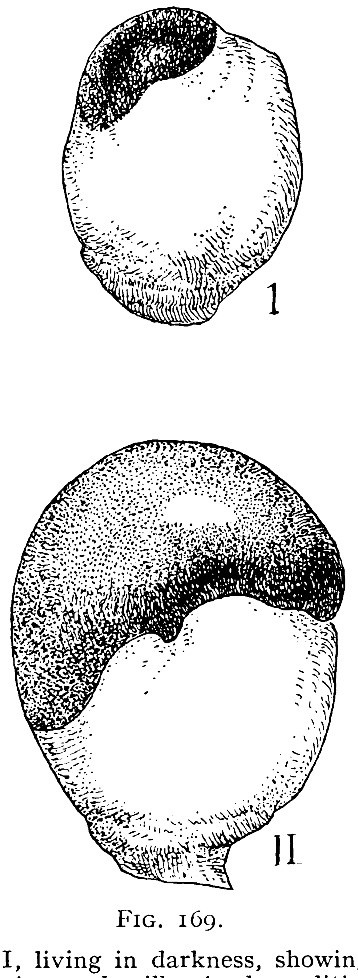


FIG. 169.

Eyes of a Crustacean; I, living in darkness, showing relatively small pigmented area; II, living under illumined conditions, showing relatively large pigmented area. After Doflein, enlarged.

of its home or uprearing". "It is five to ten times as profitable for a child to be born of parents of sound physique and of brisk, orderly mentality, as for a child to be born and nurtured in a good physical environment."

Having thus given four reasons which warrant us in regarding the first factor—Heredity—as fundamental, let us state some of the reasons for continuing to attach great importance to Nurture. We have no statistics to offer, nor biological experiments of our own to

which to refer; yet we think that what we have to say may be subscribed to by all well-informed biologists as a fair statement of the biological theory of nurture. Pearson has emphasised the importance of the inherited nature, and we agree; our aim is to emphasise the importance of nurture as well.

I. It must be noted first of all that since both are indispensable there is no antithesis. As one of the leaders of the experimental study of heredity—Prof. T. H. Morgan—has said: a "character is the product of a number of genetic factors and of environmental conditions"; or, again, "every character is the realised result of the reaction of hereditary factors with each other and with their environment"; or again, "it is a commonplace that the environment is essential for the development of any trait, and that traits may differ according to the environment in which they develop."

We have admitted that the strength of an (inherited) individuality may be such that it expresses itself almost in the face of inappropriate nurture; but there is a minimum nurture necessary if there is to be development at all; and the conditions of nurture determine whether the expression of the inheritance is to be full or partial, abundant or stunted, or it may be, as regards a particular feature, absent altogether.

Gudernatsch has shown that in tadpoles fed on thyroid there is differentiation without growth; while in tadpoles fed on thymus and spleen there is growth without differentiation.

A character known to be part of the inheritance may remain entirely unexpressed in the individual development because certain environmental conditions are lacking; yet the heritable character may be handed on all the same.

Fruit-flies (*Drosophila*) of a Mendelian race with a peculiar abnormality may appear perfectly normal if raised in a dry bottle, but the presence within them of the hereditary factor for "abnormal" may be demonstrated by rearing their offspring in a wet bottle.

A striking illustration of the present point concerns the red Chinese primrose (*Primula sinensis rubra*). Reared at 15–20° it has red flowers; reared at 30--35° C., with moisture and shade, the same individual plants have pure white flowers. The development, so far as colour goes, depends on its nurture.

Take another illustration from the Fruit-fly. There is a mutant stock that produces supernumerary legs, a considerable percentage in winter, few or none in summer. Miss Hoge finds that when the flies are kept in an ice-chest at a temperature of about 10° C. a high percentage of flies with supernumerary legs occurs. In a hot climate there would be no evidence that the peculiarity was part of their inheritance; in a cold region it would be obvious. This shows that the expression of the inheritance as regards a particular character sometimes depends on nurture.

In the dark caves of Dalmatia lives the well-known blind salamander Proteus, nearly a foot long, with a white skin, a little pinkish because of the blood. Its white skin is like a photographic plate, as Gadow puts it, for if there is the least light it becomes spotted with grey patches, and in diffuse light it becomes black. The newly hatched descendants of these dark parents are also dark; but this is probably because the light gets through the body of the parent and influences the eggs before they are laid. In any case, it depends on nurture whether a Proteus is white or black.

II. While some developing organisms are strikingly indifferent to changes in their environment, there are others which respond sensitively, sometimes in a startling way, to changes which do not seem very drastic. MacDougal's well-known experiments of injecting solutions of sugar, calcium, potassium, and zinc into the developing ovaries of one of the Evening Primroses resulted in a small percentage of notably atypical individuals, which bred true to the third generation. The chemical reagents introduced were not very different from those which might occur naturally in the sap of the plant. Among the changes induced there were not only losses and augmentations of what was previously present, there were distinct novelties which maintained their distinctness when crossed with the parental strains.

Loeb showed that it is very easy to produce a percentage of fish-embryos (Fundulus) with defective eyes, by adding a minute quantity of potassium cyanide to the water, or by exposing the newly fertilised eggs to low temperature. That is to say, relatively slight environmental changes may so alter the constitution of the developing embryo that a leap is taken in the direction of blindness.

Similarly Stockard has shown for the same fish that the addition of a very minute quantity of magnesium salt to the water induces in a large number of them the development of a single Cyclopean eye in place of the normal two eyes.

Such cases are to be borne in mind in connection with man and mammals where even slight extrinsic or exogenous changes in the blood of the mother may affect the development of the unborn offspring living in intimate symbiosis with her. It is very important to realise the difficulty of distinguishing between what is due to inherited nature and what is due to some peculiarity in ante-natal nurture.

The effect of negative nurture on the individual is sometimes very remarkable. It is well known that certain simple worms (Planarians) can be starved for months without fatal effects. They become smaller and smaller, living on their own internal resources. Some of their cells disappear altogether, and others are greatly reduced in size. This is an old story; but Child has more recently shown that the reduction in size is associated with a remarkable rejuvenescence, and

that the vital processes are quickened. The starveling becomes young again—surely a quaint biological justification of asceticism. Many similar facts are given in Child's *Senescence and Rejuvenescence* (Chicago, 1915).

And what is true of nutrition is true of other factors in nurture; they alter the punctuation of the life-cycle. A herring's egg in the sea hatches in a little over a week; put it in a refrigerator and the development is slowed down so that the egg takes fifty days to hatch.

III. Without assuming that a peculiarity of the body, acquired as the direct result of a peculiarity in nurture, can be as such or in any representative degree entailed on the offspring, of which there is insufficient evidence, we must recognise that nurture may be of considerable importance to the race. The modification may give the individual a life of conspicuous success or failure, which may result in a subsequent increase or decrease in the numbers of the type which it represents, thus obviously working for both good and ill to the race. Vigour acquired by open-air exercise gives a man resisting power against infection; it may keep bad constitutions alive; it will also keep good constitutions from being gratuitously weakened. Reduction of the likelihood of infection will also work both ways.

It has often been pointed out that an individually acquired modification may serve as a life-saving screen until an innate variation with similar result has time to establish itself. Thus artificial immunity may be a useful temporary modification until natural immunity arrives—if it does arrive.

In the case of mammals the unborn offspring may be damaged by the ill-nourished, over-strained, or poisoned state of the maternal body. There is not transmission of acquired characters in the technical sense, but there is ante-natal deterioration and arrestment of the offspring as the result of abnormal nurture on the parent's part. Some evidence exists which goes to show that deeply saturating parental modifications, such as the results of poisoning, as by syphilis, may affect the germ-cells. The influence very probably affects the cytoplasm rather than the chromosomes.

There is little likelihood that we are at an end of the question as to the possible effect of modifications (nurture-effects) on inheritance; and a useful hint of the subtlety of the problem may be got from a brief consideration of one of the most important British investigations on the subject—Agar's study of a water-flea (Simocephalus), a little crustacean with two valves. Under certain nutritive conditions the crustaceans acquired a peculiar folding-back of their shell-valves, doubtless as the result of altered metabolism. After the eggs had appeared and grown in the ovary, the animals were restored to normal conditions. In due time the eggs developed into

forms with reflexed shell-valves such as their parents had acquired. Later on, however, when the parents laid again the abnormal effect was seen only to a very slight degree, and in a third brood it had dwindled away. The probability is that the abnormal nurture resulted not in any disturbance of the inheritance, but in the formation of some peculiar non-living metabolic product, which was included in the cytoplasm of the egg, passed passively into the body which developed from the egg, and there produced on the body of the offspring the same effect as it originally produced on the body of the parent which acquired the character in question.

In this connection reference may be made to a view sketched by an ingenious French biologist, Bohn. In one aspect the organism is a vast system of correlated chemical processes. There are numerous main lines of metabolism which work together. If conditions demand it, there may be a great local increase along any one of these lines, just as in the activities of a country. Thus, hard exercise of the limbs may induce unusually intense myogenic metabolism—the development of muscle substance. This is seen in the professional dancer, for instance. But because of correlation—a fact imperfectly understood—the myogenic fashion, so to speak, spreads, and affects other parts of the body, such as the dancer's heart. Now it may be that although the germ-cells remain unaffected by any particular muscular modification, they may be specifically affected by a general dominance of myogenic metabolism.

Very striking and suggestive are Child's experiments on the effect of altered diet on Planarian worms. Thus a diet of freshwater mussel depresses the vitality, i.e. lessens the rate of metabolism and the power of resistance. The stock becomes senescent, and if the diet be continued for several generations there is an aggravation of senescence, for they begin to be born old. The effect of the mussel diet is cumulative. One does not thereby argue from worm to man, but one recognises the importance of competent experiments which show that the course of the life-cycle may be greatly altered by changing the character of the food.

Bordage made some interesting observations on European peach-trees transported to Reunion. As has been noticed in similar cases, they dropped their deciduous habit and became—it took some of them twenty years—evergreen. The individual constitution was altered. Still more interesting was the fact that when seeds of these neo-evergreens were sown in certain mountainous districts with a considerable amount of frost, they produced young peach-trees which were also evergreen. European seeds sown in similar places produced ordinary deciduous trees. Yet it is possible that the apparent inheritance in the case of the evergreen peach-trees was the result of an influence on the body of the seed before it was

separated from the parent. A similar result in mammals might be readily confused with inheritance.

IV. There is an increasing body of facts pointing to the conclusion that changes in nurture may serve as variational stimuli; that is to say, that they may affect the germ-cells through the parent, so that a variation occurs in the offspring. Thus, Tower subjected potato-beetles, at a certain stage of their development, to unusual conditions of temperature and humidity. The body of the beetles exhibited no modification, and that was not to be expected. But in a number of cases the offspring of these beetles showed remarkable changes in colour and markings, and even in minute details of structure. And there was no reversion to the parental condition. Tower's experiments require confirmation and extension, but it looks as if a peculiarity in the environment might serve as a liberating stimulus to germinal variability.

Attention may also be directed to the probability that much may depend upon the nurtural reception that a natural variation meets with. Unless the nurture evolves progressively along with the nature (and in mankind especially), many new departures may be blocked at the outset; many promising variations may be born only to die, or die too soon. Does not human biography give only too many instances of this?

On no account whatsoever are we to countenance, if we can help it, spoiling good stock by bad; but it is a dubious inference that the bad is hopeless. It may often be that it is not so bad as it looks. In her interesting study, *Environment and Efficiency* (Longmans, 1912), Miss Mary Horner Thomson tells of her study of 265 children, mostly of "the lowest class" (Class A, fourth below the poverty level!), who had been sent to institutions and trained. She found that 192 (72 per cent.) turned out well; that 44 (16 per cent.) were doubtful; and that only 29 (less than 11 per cent.) were unsatisfactory, and of these 13 were defectives. These figures, which other good orphanages justify, but which should be widely collected and compared, afford some evidence of the controllability of life.

IN CONCLUSION.—Illustrations have been given of a number of facts: that nurture is important as a condition of normal development; that on its liberating stimuli the degree of development in part depends; that even a slight change in nurture may mean a great deal; that in mammals especially it is not always easy to distinguish what is in the strict sense inherited from what is due to ante-natal nurture; that nurtural effects, though not transmissible, may be in several ways of indirect racial importance. It has also been pointed out that there are some facts suggesting the theory that peculiarities of nurture may act on the germ-cells as variational stimuli—tending to the emergence of the new.

It would be fallacious to argue directly to man from any of the biological illustrations above given; yet surely enough has been said to suggest the undesirability of losing faith too utterly in the potency of nurture in shaping the individual life, be this organic or human. Of the danger of arguing from one case to another, let us give an interesting illustration concerning the influence of alcohol. D. D. Whitney studied the effect of minute traces of alcohol in the water in which Rotifers or Wheel Animalcules were kept. The result was a decrease in reproductive power, and a weakening in the power of resistance to deleterious influences. Twenty-eight generations were studied, and the evil effects of the alcohol were proved. But from the eleventh to the twenty-second generation at least it was found that removal of the alcohol was followed by rapid individual recovery, and that the grandchildren showed none of the defects caused by alcohol in their grandparents.

Stockard subjected male guinea-pigs for three years to vapour of alcohol, which does not spoil their stomach; and he found that an alcoholised male guinea-pig almost invariably begot defective offspring, even when mated with a vigorous normal female. The effects were manifest in the second generation also. "The poison injures the cells and tissues of the body, the germ-cells as well as other cells, and the offspring derived from the weakened or affected germ-cells have all the cells of their bodies defective." We shall discuss this rather difficult case in another connection; what we are concerned with here is illustrating the far-reaching influence of nurture.

In attempting to appreciate the importance of nurture for the individual, emphasis must be laid on its rôle in the development of the human mind; and here we are at one with many biologists and psychologists of high standing who have declared that our mind is in large measure a social product. One of the sanest of them, Prof. G. H. Parker, writes: "Our intellectual outfit comes to us more in the nature of a social contribution than an organic one." While our mental capacity is primarily determined by heredity, it can be encouraged and augmented, or inhibited and depressed, within wide limits, by nurture.

Especially as regards the mind do we feel that while the inheritance is the seed-corn, "nurture" is the soil and the sunshine, the wind and the rain. Nurture can create nothing, but without its favouring conditions our sowings fail; and the buds may fail to open, or to unfold freely, or later to blossom, or to fruit, or these to seed anew. We cannot make a silk purse out of a sow's ear, but by trading with our talent we may make it two, or peradventure five or ten talents. If man cannot add to his inheritance any new kind of talent for which he has no initiative or hereditary factor (if this indeed be possible?), he can certainly and vastly increase the value and the effectiveness of the talents with which he is born.

NATURE AND NURTURE IN EUGENICS.—As regards the Eugenic movement, with its invaluable insistence on the fundamental importance of nature, it can do this with best effect when it does not at the same time depreciate the work of those devoted to the improvement of nurture: let it rather collaborate with them. Writing in a region very actively concerned with the breeding of cattle of well-known excellence, and of these to still better qualities, it is encouraging to see also near us the active Rowett Research Institute for animal nutrition; and besides this again kindred undertakings for active experiment on the improvement of pastures, and for these of the grasses, and the soil, both separately and together; while further, all these experts, on nature and nurture respectively, are in frequent and co-operative discussion. Is it not time we were getting as far for our own species?—with eugenists meeting and co-operating with educationists, and these also with sanitarians and town-planners? Why not organise this, and no less definitely, between their respective but still too specialised societies? Here, for instance, the British Association is increasingly setting an example, in holding conferences between its sections, and by devoting its South African meeting of 1929 to applied science.

Let us face that difference between the biologically and the socially minded, which not only impedes such co-operation as just pled for, but substitutes unnecessary controversy, if not even alienation. It is plain that the biologist is rightly insistent on that process of organic heredity on which the continuance of all forms of life depends, and its quality also, and so of course for man and beast essentially alike. Every serious student of social science is of course bound to accept this, as well as all other verified teachings of biology, and other sciences preliminary to his own, though he may well confess not to be so fully at home in all these as he should be. Yet it is for the biologist in turn to recognise that sociology has also its own essential characteristic conception of transmission—that of the Social Heritage. For this every human being—not abnormally arrested at the purely organic level, as deeply defective—is also, as a social being, the advancing heir of all such accumulated results of social life and activity as can come or be brought within his life-reach. And thus not simply of such socially inherited and acquired access to the material means of life-maintenance as may be, but also to that far vaster immaterial heritage, through which his family, community, etc., are truly and socially human—witness language, with the long and wide traditions which it bears; and of course the like for institutional life as well. Hence so long as biologists in general, and eugenists in particular, remain (or let themselves appear) inadequate as sociologists, through under-appreciation of the Social Heritage in its full significance, and its needed increasing

openness to all, their present legitimate and needed insistence on the very real importance of organic and psychic Heredity cannot but appear unduly stressed. Is it not thus that eugenists fall short of evoking the social attention they justly desire, and the social response which their good counsels deserve? It is thus a most regrettable fact that eugenic teachings—so far as specialised upon family Heredity, without correspondingly expressed appreciation of the common social Heritage, to which good heredity so widely opens—have too often come to seem reactionary, to great masses of the public they appeal to, and even to their leaders as well. For these, especially for the past century and a half, have been increasingly aspiring to enter more and more fully into the Social Heritage, to advance its progress and to abate its associated burdens. And this the more since not a few of these burdens have undeniably been in the past—and sometimes still too much are—associated with a (pre-biological, insufficiently eugenic, and thus excessive) stress upon Heredity, and this towards too much monopolising of the Heritage.

In short then, the progress both of biological and social science is delayed, and still more that of their social applications, until their respective cultivators more definitely combine. Combine in what? In the co-adjustment of (1) the fundamental truths and counsels of biological Heredity—with its insistence—which every intelligent and open social mind must come to recognise and utilise—on the importance of good stock, and even of lives made and kept as pure and strong as may be—with (2) the supreme social truth and insistence of sociology for the Social Heritage; and this with resulting recognition of its progress—understood as essentially a matter of acquired characters, accumulated and transmitted, in, by, and for the ever-widening community, and thus as far as may be above, beyond, and irrespective of any and all limitations or advantages of breed and birth.

As such harmony—not simply of aristocracy and democracy, but say rather of Aristogeny and Demogeny (ontogeny and phylogeny, too)—gets more clearly on its way, the legitimate materialisms of biology—as for eugenics, and for euthenics as well, i.e. its due insistence on nature and nurture together, each for all they can yield—can no longer seem discordant or indifferent to the people, with their ever-widening social aspirations. It is now full time for both vitally to unite, and towards freshened and fertile development, both of Society and its Individuals; and these seen, and self-realised, as veritably each a "socius", and all as Socians. In such fully evolutionary development of race and its members together in fruitful interaction, we cannot but foresee—and with increasing acceleration—the long-dreamed and often-striven-for coming of the Kingdom of Life on earth as it may be discerned in the ideal. For the reunited

Life-sciences—the organic, the social, and the psychological and ethical with these—cannot but thus boldly re-express this ancient ideal for Humanity (indeed with all the other forms of life it can associate), as Etho-Polity, of Parnassolympians, in Eutopia.

CHANGES OF BEHAVIOUR AND REACTION AMONG LIVING ANIMALS

One of the characteristics of life is plasticity; but it is not always in the same way that living creatures become suited to new circumstances. Sometimes an intelligent change of habit is effected very rapidly. Thus it is not more than a century since sheep were taken to New Zealand, but in less than that time the naturally vegetarian or frugivorous Kea parrot (*Nestor notabilis*) has learned how to tear away the fleece from the loins and get at the fat and flesh above the kidneys. They usually attack sickly or fallen sheep, but they sometimes kill normal animals, and in either case the new habit is a very remarkable one. Some suggest that the big-brained birds mistook resting sheep for moss-mounds, in which they are said to dig for insects! More probably the birds may have begun by pecking at the fat adherent to sheep-skins pinned out to dry. Many discoveries among animals (much as in mankind) are thus made half-fortuitously; and intelligence is shown in the way the discovery is appreciated and utilised. Big-brained birds like parrots are not slow to take a hint, and the new device would probably spread by imitation.

CHANGE OF DIET IN GULLS.—The Herring Gull and the Lesser Blackbacked Gull are characteristically fish-eaters; but it has been well known for a long time that they are not averse to eating corn in the harvest fields. But this tendency to vegetarianism has become increasingly marked in Scotland during the twentieth century. Two or three hundred gulls may be seen busy among the stooks on a single field of corn, and they also gouge out the insides of turnips in a systematically disastrous way. They will even dig up potatoes near the surface. The chief reason for this inland vegetarian feeding is probably that the numbers of Herring Gulls and Lesser Blackbacks have greatly increased, partly through protection, and partly because the birds of prey that used to devour the young have become scarce. The White-tailed Sea-Eagle is no longer to be found in Scotland; the Raven has practically gone, and the Peregrine Falcon is rare. It is probable that the increase of trawling has restricted the readily available fish-supply for Herring Gulls and Lesser Blackbacks; and this would naturally suggest to shrewd birds the exploration and exploitation of other fields. So there has been, to man's loss, an intelligent and rapid change of habit. It may be noted in passing that the multitudes of small Blackheaded Gulls

often seen in the fields are mainly to the good, since they are predominantly insectivorous, and destroy huge numbers of injurious pests.

Slow Changes of Intelligent Behaviour.—It is easy to put a date-limit to the Kea parrot's change, namely the introduction of sheep into New Zealand. There are also many observations to show that the Herring Gull and the Lesser Blackback have changed their diet in increasing numbers of recent years. But there are other cases of similar changes which must have taken a much longer time. The Robber Crab (*Birgus latro*), common on Christmas Island and the like, is a giant relative of the hermit-crabs in shore waters. But it has become terrestrial, and does not require to go to the sea except to spawn. This change of habitat from water to land must have required a very long time, for it is associated with a change in the breathing organs—a change which could not be effected quickly. The Robber Crab has to breathe atmospheric air, not air dissolved in water, as ordinary Hermits do. But what we are concerned with at present is something different—namely, the Robber Crab's novel habit of climbing the stems of the Coco-palms in order to secure the nuts. With its heavy claws the crustacean makes a hole in the nut and spoons up the flesh. The broken shell may be afterwards used, in Hermit Crab fashion, as a shelter for the tail. Now this extraordinary habit of climbing the Coco-palm could not, we think, be learned in a day; and yet it must have been learned, and not so very long ago, for the Coco-palm is not a native of these parts. The Coco-palms of Christmas Island must have sprung from nuts wafted by currents from distant shores. Let us be clear, at this point, that Hermit Crabs have an instinct—an inborn, hereditary, racial predisposition or prompting—to shelter their vulnerable sensitive tail in some borrowed house, usually the shell of a whelk or some other sea-snail. The Robber Crab's tail is not soft as in Hermits, yet Birgus is true to the ancestral instinct to seek some extrinsic shelter, such as the personally secured shell of a coco-nut, or the fortuitously discovered empty beef-tin. Such is an instinctive prompting, but the climbing of the Coco-palm is surely an intelligent response to a new situation. We take it as an instance of a new habit adopted intelligently, but probably requiring generations of testing before it became part of the orthodox routine of life. Organic Evolution is a long drawn-out commentary on the text: Test all things and hold fast to that which is good.

The case of the Robber Crab and the Coco-palm seems to us to illustrate well what is so often ignored in conventional ætiology, that all robust, resolute animals share in their own evolution. They are not inert items being sifted against an inexorable sieve, they are also individualities which struggle and strive. They are not mere pawns, moved by a callous Environment; they are living creatures

that insist on sharing in the game, and so making more of their environment than did their predecessors. No doubt each receives by heredity its particular hand of cards, beyond which it cannot go; but it is more or less open to each organism to play the hand for all it is worth.

New Associations.—Inborn in many animals are certain reactions which always occur in answer to a particular stimulus. When the earth vibrates the worm jerks itself back into its hole; and when the action is as simple as this, it is called a reflex. The brain is not needed, and the action is involuntary. As explained in the section on Behaviour, a stimulus from the outside world is received by sensory nerve-cells (S); the thrill passes to associative nerve-cells (A); it is shunted to motor nerve-cells (M), which command the effector (E) muscle-cells to contract. We may indicate the stages of a simple reflex action (sensory, associative, motor, effector) by their initial letters—$S \rightarrow A \rightarrow M \rightarrow E$; and as it often happens that one reflex action sets another at work, as sucking is followed by swallowing, this might be conveniently indicated by $S \rightarrow A \rightarrow M \rightarrow E$, followed by $\mathrm{s} \rightarrow \mathrm{a} \rightarrow \mathrm{m} \rightarrow \mathrm{e}$, followed by $s \rightarrow a \rightarrow m \rightarrow e$. Such a chain of reflex actions forms instinctive behaviour, considered from the physiological side; but many instincts have probably more or less of a psychological side as well, being suffused with awareness and backed by endeavour. A hive-bee on one of its first open-air explorations forces its way into a difficult flower, it collects the pollen, it stows it away in its pollen-baskets; and, when these are full, it makes a bee-line for home. It has not to learn to do these things; the capacity of doing them is part of its hereditary make-up. An instinct is an inborn ready-made power of doing apparently clever things. Now the meaning of this digression is that in new surroundings or circumstances animals have very little power of changing their *instincts*; what they may be able to change are their individually learned associations, which may thus develop into intelligent habits. The difference makes the whole problem of change or no change more intelligible. When a young partridge or redshank hears its parent's danger signal it is bound to squat and remain motionless. This is instinctive behaviour. But when a mother otter is teaching its cubs how to behave when the hound's bark is heard, it is establishing an association; and when it is teaching them how to guddle for trout or how to eat frogs, it is appealing to their dawning intelligence. The habits built up on the basis of association or of intelligence are more or less changeable if the conditions of life change. In short, the more instinctive an animal is, the less plastic it is; and the more intelligent an animal is, the more educable it is. When the schoolboys in the Mediterranean pine-forest adjust a moving Indian file of the Procession Caterpillars so that the head of A is brought round to touch the tail of Z, the larvæ may go

circling on for hours, obeying their instinct, unable to break the spell. But everyone knows that intelligent mammals can be trained to do all sorts of unusual things.

New Modifications.—This word "modification" is applied by naturalists to individual changes of structure, or of function, that are directly due to some change or peculiarity in surroundings, food, or habits, and that last after the inducing cause has ceased to operate. If a man goes to the Tropics for some months he may become very brown or freckled. This means that an unusual amount of the dark pigment called melanin, familiar in negroes, is deposited in the skin. There is an advantage in this, for it may save the skin from being burnt in the glare. This kind of change is very common, and it is called an *adjustment*, the point being that it does not last. After a few months at home the extra pigment has been absorbed, and the man is as he was. But if he has stayed thirty years in the Tropics he may become so thoroughly tanned that he will remain brown after he returns to England for the rest of his life. This would be called a *modification*, or individually acquired character. It lasts after the inducing cause has ceased to operate, but there is very little evidence that it can be entailed on the offspring in any representative degree. But this is a separate problem which we have separately discussed; let us rather give some examples of modifications.

If sheep are taken to a much colder climate they sometimes grow a thicker and longer fleece—a useful protective modification. In the next generation the wool is still longer and thicker, and this is natural enough, since the offspring are under the influence of the cold from birth onwards, while the parents experienced it only after their arrival. It has not been shown that there is any further increase after the first generation born in the new country.

Similarly, if plants are transported from a low-lying region to the high Alps they may develop a thicker skin or more hair on their leaves—a protective modification which their offspring may show even more markedly. If the plants are taken back again to the low ground the individual leaves remain as they became on the mountains, but the new leaves and the leaves of the offspring may be entirely of the low-ground type. The Alpine modification does not last; and the same is true of the changes that follow exposure to desert conditions, or the like. Some cases are between "adjustments" and "modifications".

The experimental evidence of plasticity or modifiability is often very striking. As we have already mentioned, there lives in the caves of Carinthia and Dalmatia a wan, blind newt, called Proteus. It is about six inches long, and shows no colour except where the red blood shines through the three pairs of external gills. The eyes remain arrested in development and do not reach the surface. But if Proteus is brought from the cave to the new environment of a well-lighted

laboratory it begins to develop spots, and in a week or two it is dark-coloured like a common newt. And if a larval Proteus is reared under red light, its eyes grow larger, reach the skin, and become seeing eyes. The reason for red light is that white light would evoke a dark skin, thus preventing the light from reaching the developing eyes.

An experiment in the opposite direction illustrates what may be called a *minus* modification. A goldfish was kept for three years in complete darkness, care being taken to secure abundant food and freshness. The result was complete blindness, which was indicated in the structure of the eye by the degeneration of the rods and cones—the percipient elements of the retina. This proved that the normal stimulus of the light is required in this animal to keep the structure of the eye up to the mark. The experiment would have had even greater interest if it had led to some knowledge of the state of the eyes in the blind goldfish's offspring, but there are not as yet any data on this subject.

CAVE ANIMALS.—Many of the animals, e.g. fishes, crustaceans, and insects, that live permanently in caves are more or less blind, depending mainly on their other senses, especially touch and smell. There are many different gradations in the state of the eye in different cavernicolous types, but some species are entirely blind. To some naturalists it seems justifiable to say that the blindness illustrates the hereditary accumulation of the results of disuse and darkness. But it is necessary to proceed cautiously. As we have already explained, part of the blindness of Proteus is the outcome of an influence operating on each successive crop of individuals, for under the red light in the laboratory the usually arrested eyes may become seeing eyes. Therefore the sense of sight is not actually lost to the race. Perhaps the same is true of other blind cave-animals. They are certainly walkers in darkness, but it is possible that they may recover their sight. No one knows, for no one has tried with sufficient care, what may follow restoration to the light.

But there is another point to be considered. Eyes are very variable structures, meaning by variable that they may be better or worse from birth onwards, apart from the direct influence of illumination or of darkness. A variation is an inborn peculiarity whose origin is still obscure; it is the outcome of some *germinal* change and is quite different from a bodily modification. It is increasingly explained (so far) as due to some disturbance or rearrangement, some strengthening or weakening, of the hereditary items or "factors" that make up the inheritance carried by the egg-cell and the sperm-cell. Albinism, the absence of pigment, may be mentioned as an example of a minus variation; the appearance of long Angora hair in various types of mammal is a plus variation. In regard to many variations we know that they are readily entailed by heredity on the off-

spring; and this is more than we can confidently say in regard to modifications.

Now let us return to the cave. It may be that the blindness illustrates the hereditary accumulation of the results of disuse and darkness; but there is little experimental evidence in support of this possibility. It requires fewer assumptions to suppose that variants changing in the direction of poor sight, as many variants do, found their way into the grateful shade of the cave, and continued to vary in the same direction. The passage towards complete blindness would be assisted by Nature's sifting out of all increases in useless organs.

MADEIRA BEETLES.—Darwin was much interested in the beetles of Madeira because they illustrated so well his theory of Nature's Sifting or Natural Selection. In its simplest terms, his theory was that new departures or variations, which are always cropping up, are sifted in the struggle for existence. Any variation that gives its possessors some appreciable advantage will tend to secure their survival, while a variation that handicaps its possessors will tend to their elimination. Thus the fitter, which means the better suited to particular conditions of life, will automatically tend to survive. The struggle for existence, which does the sifting, includes all the answers-back that living creatures make to environing difficulties and limitations; it means much more than internecine competition among fellows, it may be a struggle against a changeful environment, against foes of an entirely different type; it may even be other-regarding as well as self-regarding.

As to the beetles in Madeira, the peculiarity is that so many different kinds are wingless. Out of the 580 species of beetles that were known in Madeira when Wollaston made his study, over 200 are so defective in wing-development that they cannot fly. Moreover, of the twenty-nine genera peculiar to the island, no fewer than twenty-three have all their species flightless. What is the meaning of this? It has no doubt something to do with the fact that Madeira is wind-swept, so that there is great risk of flying beetles being blown out to sea. But it is necessary to be more precise. The non-flying beetles did not intelligently shed their wings so as not to be blown away, for they are hatched out from the pupa-state without wings, or with no more than vestiges of wings. It is an old-established constitutional peculiarity, we may be sure of that; and it is seen in many beetles which live in haunts where they are not exposed to wind.

Another possibility is that the native beetles of Madeira learned to lie low, and in the course of generations lost their wings by disuse. But, as we have said, there is little evidence that the results of disuse can be hereditarily entailed. On the whole, the probability is that Nature's sifting favoured germinal variations in the direction of

wing-reduction. But, to be quite fair, let us quote Darwin's precise sentences from *The Origin of Species* (1859). "Several conditions make me believe that the wingless condition of so many Madeira beetles is mainly due to the action of natural selection, combined probably with disuse. For during many successive generations each individual beetle which flew least, either from its wings having been ever so little less perfectly developed or from indolent habit, will have had the best chance of surviving from not being blown out to sea; and, on the other hand, those beetles which most readily took to flight would oftenest have been blown to sea, and thus destroyed."

FAILURES IN ADJUSTMENT.—The Barnacle Goose (*Bernicla sandivensis*) of the Hawaiian Islands has become entirely a land goose during the breeding season. Moreover, it shows an obstinate rigidity in always going back to the same breeding-place, an attachment which enemies, including hunters, recognise to their own advantage. Moreover, the parents are moulting when they lead the goslings about, so that they cannot fly away; and they have left the vicinity of the sea in which they used to find refuge. There are many instances of this sort of imperfection in habit-change. And the apparent imperfections become striking, though fallaciously so, when man enters into the plot. Thus the now much reduced Elephant Seal, once very abundant on Californian coasts, persisted in being unafraid of man. But how can one expect giant animals to have a tradition of timidity? How can one expect animals that have held a position of security for tens of thousands of years to react adaptively to man's mischievousness in the course of a century? For thousands of years they have known no fear; is it any imperfection that they remain unafraid of a few men intruding from a ship's boat? We do not absolve them, so to speak, from being somnolent in security, but we cannot think of them as stupid.

CONCLUSION.—There is no doubt that animals can adjust themselves, and sometimes adapt themselves, to new conditions of life. There may be changes in structure and changes in habit. The fact that some animals are profitably plastic, while others are fatally stereotyped, is probably because those "habits" that are based on reflexes and instincts are very hard to change; while those that are based on intelligence and on individually-learned associations remain effectively plastic. Animals that are predominantly instinctive—a line of evolution with many advantages—tend to become stereotyped. For effective change of habit we must look among animals whose ways of life are chiefly based on intelligence. The instinctive line of evolution led to extraordinarily effective results, as in ants, bees, and wasps; but the intelligent line of evolution is the open path of educability.

Is Training Transmissible?—When Prof. Pavlov, the distinguished Russian physiologist, was lecturing in Britain several years ago he unfortunately put into circulation a curious tale in regard to the hereditary transmission of the results of training. He trained some white mice to associate the ringing of an electric bell with the filling of their feeding-trough, so that after three hundred lessons what is called a "conditioned reflex" was established, and the mice came running whenever the bell was sounded, although there was no food forthcoming as reward. This sort of learning is well known among animals, both of high and low degree. But Pavlov was understood to have said that the children of these mice required only a hundred lessons, and the grandchildren only thirty. The inference that the results of training were being transmitted was corroborated in the next generation, when five lessons sufficed. This story was so circumstantially reported that it found its way into books, such as Prof. E. W. MacBride's *Introduction to the Study of Heredity*; and if it had been true it would have been one of the most important experiments in the world. It would have served as a welcome buttress of Lamarckism, and it would have put heart into educational efforts. But the fact is that Pavlov has entirely withdrawn his statements as to the hereditary transmission of the "conditioned reflex", serious defects having been discovered in the process by which the positive conclusions had been reached.

Before Pavlov's revocation was published, somewhat similar test experiments were made in 1924 by Dr. E. C. MacDowell, working at the Carnegie Institution, Long Island. He trained white rats to master a maze of the Hampton Court type, and afterwards did the same with their offspring and grand-offspring. We do not gather from his paper how many rats were used, but MacDowell's conclusion stands out clearly that the training of the ancestors did not facilitate the process of learning on the part of their descendants. "Children from trained parents, or from trained parents and trained grandparents, take as long to learn the maze habit as the first generation trained."

A repetition of Pavlov's experiment was begun by Miss Isobel Dean in 1925, working in the Zoological Laboratory in Aberdeen University; but it had unfortunately to be discontinued after the second generation. One striking fact was soon evident, that the Aberdeen mice were much quicker in the uptake than those of Petrograd. For the males there were hints of the establishment of a conditioned reflex as early as the twenty-sixth meal; and by the fortieth meal the association of food and bell had been acquired by them all! At that stage, whenever the bell began to ring, which was two or three seconds before the door to the food was raised, there was a general rush of the mice from the upper floor, where they all were at the time. The response was so immediate, the mice eagerly

rushing down the stair or climbing down the wire-netting, that there could be no doubt as to their associating bell and food. The females learned a little more quickly, showing first signs of recognition after twenty-four meals, and learning definitely after thirty-seven lessons. What a contrast to Pavlov's three hundred! It need hardly be said that the mice did not see their teacher at meal-times.

A hundred and forty meals were given, but after the fortieth there was no appreciable difference in the manner or the average rate of the response. But there were marked occasional variations, apparently connected with appetite, and some individuals seemed more alert than others. These experiments began with twelve males and eleven females, and were continued for about two and a half months, when the numbers had been reduced by disease and accidents to seven and eight respectively. The bell-ringing then ceased, and the mice were paired, yielding eventually a first filial generation of seven males and 14 females. In due time these were ready for lessons exactly similar to those their parents had received. Miss Dean found that the first hints of recognition appeared in both sexes at the twenty-sixth meal; and that all the males had learned after forty-four meals, and all the females after forty-six, rather longer than before! Thus the net result was negative; the rate of learning had not changed appreciably. But no one will attach great importance to experiments extending over no more than two generations.

This brings us to the experiments on white rats, begun in 1920 by MacDougall, the well-known psychologist, at that time in Harvard. He does not claim to have established the validity of the Lamarckian principle—i.e. the transmissibility of representative results of acquired modifications, but he thinks that his facts point towards this conclusion. His first notion was to train the rats to run in a hollow wheel like a squirrel-cage, which included an electrified section whose mild shock could be evaded by a jump. The rats soon learned to run the wheel smoothly and to leap prettily across the electrified section. But in the following generations there was anything but improvement. A tendency developed to dash up the sidewall instead of leaping. Though the bolder spirits would still leap, there seemed to be a growing timidity or hereditary phobia, which rather spoilt the experiment.

The next experiment was made with an ingeniously contrived tank, so adjusted that a rat placed in the water could find its way out by either of two routes—one gangway (*b*) electrified and illumined, the other (*a*) with free egress, but not lighted up. The question was how long the rats would take to learn to avoid the less desirable way out, and whether the number of trials would diminish in the course of generations of training. Sometimes the bright electrified gangway was alternated in position with the dim safe gangway, and untrained rats were of course used as controls. The general result,

which should be critically examined by those sensitive to statistical fallacies, was to show on the part of the trained tank-rats a predominance of the dim route more decided than the slight predominance in the same direction which marked the behaviour of the control rats. To the cold-blooded outsider it does not seem that the difference is very striking; and it is not claimed that the experiments have as yet shown that there is in the course of generations any regular increase of facility in learning the lesson. But the results certainly justify an open mind and the continuation of these and similar experiments.

Supposing there is evidence of the Lamarckian transmission of the effects of training, MacDougall inquires into the nature of that which is transmitted. "What is that function which seems to be accentuated in successive generations of the tank-rats as a consequence of the training process?" He is inclined to answer: "A general increase of timidity or caution, a greater susceptibility to fear, an increased strength or sensitivity of the fear instinct." Whether this specifically prompts to avoidance of the illuminated pathway, the expert declines to say at present. But the less specific the response, the less is its convincingness as regards Lamarckism, for general increase in timidity and "nerves" may surely arise as a germinal variation, apart from the particular experiences in the individual lifetimes. But our thanks are due to MacDougall for continuing these laborious experiments for six years and for seventeen generations —"representing in human terms a period of some five centuries". To say the least, he has kept this momentous question open: Are the results of individual experiences representatively transmissible?

ALCOHOLIC RATS.—Numerous experiments have been made in America to test the hereditary effects of subjecting successive generations of rats to alcohol fumes. A recent investigation, by Prof. F. B. Hanson and Florence Heys, of Washington University, St. Louis, dealt with ten treated generations of albino rats (*Mus norvegicus albinus*) and corresponding controls. The precise problem was this: Do the descendants of treated rats, having ten generations of alcoholic ancestry, possess any greater power of resistance to alcohol fumes than the descendants of control rats of entirely non-alcoholic ancestry? The outcome of the experiments was to show that no increased resistance to alcohol acquired by individuals during their lifetime is in any degree passed on to their progeny. There was no cumulative effect of ten generations of acquired resistance, and no inheritance; the individuals of each generation re-acquired the resistance as their parents and grandparents had done before them.

Increased resistance to alcohol fumes is a physiological character, gradually built up within the system, involving complex chemical

changes. Though functional rather than structural, it is an acquired character in the Lamarckian sense, changing the physiological reaction of the entire organism to an external stimulus. And, as the result of the work of Hanson and Heys is to show no trace of the handing on of the acquired resistance, no support for the Lamarckian hypothesis is forthcoming along this line.

ALCOHOLIC DEGENERATION IN RATS.—As there has been some discrepancy in the results of treating animals for successive generations with alcohol fumes, we may sum up the present state of the case: (1) Stockard and Papanicolaou found that the untreated offspring of treated guinea-pigs were defective in fertility and in the quality of the offspring they produced. This was attributed to a deterioration of the germ-cells. (2) But Raymond Pearl got the opposite result with his hens, finding that in eight points the offspring of treated parents, either one or both, were superior. This was attributed to an elimination of the weaker germ-cells. (3) Stockard accepted Pearl's idea of the selective agency of alcohol, but retained a belief in general deterioration of germ-cells. The weakest were, he supposed, entirely eliminated, but the survivors were also weak, and gave rise to defective offspring, which often died before birth or soon after. Those offspring which lived to reproduce gave birth to defective offspring because "weak cells give rise to other weak cells". (4) Hanson holds that alcohol acts as a selective agent only, and produces no new, heritable variations. In their recent paper, Hanson and Heys write: "It seems evident that none of the experiments with alcohol thus far presented gives any indication that alcohol has produced a specific alteration of germ plasm, as would be demanded had an acquired character been transmitted." (5) It appears to us, however, that Stockard's result indicates general deterioration of the germ-cells as well as the elimination of the weakest. Though this may not involve "a specific alteration of the germ plasm", it may imply a weakening of the whole stock. A weakening of the germ-cells may operate in a very deteriorative way, not only by sapping developmental vigour, but by disturbing the regulative processes on which normality depends. The last word has not been said. We are all tired of alcoholised rats, yet we must hear about them again.

MELANISM IN MOTHS, AND ITS CAUSES.—The most noteworthy evidence so far for the evolutionary influence of environmental conditions upon insects are the recent studies of Harrison and Garrett on the development and rapid progress of melanism, in species after species of British moths. This change is confined to the industrialised districts, and is also being reported from those of Germany and the United States. Smoke and light deficiency, dampness, etc., having proved inadequate as explanations, even when supplemented by natural selection, the suggestion next arose

"that metallic salts ingested with the larval food of affected species might so act directly on their germ-plasm as to alter its potentialities". And as smoke-deposits on the leaves of food-plants are found to contain relatively large quantities of salts of manganese and other metals, and so on hawthorn leaves in such districts also, careful experiments were carried out by rearing larvæ of successive generations upon such food-plants, with Mendelian carefulness of records, and with due controls. The title of their Royal Society paper (1926)—"The Induction of Melanism in the Lepidoptera, and its Subsequent Inheritance"—summarises their results; so their conclusions may be briefly cited. First, that these "experiments demonstrate, without possibility of contradiction, that the germ-plasm can be influenced by external agencies. Irrespective of Lamarckian views they supply what evolutionary theories all lack, an experimental demonstration of at least one cause of variation: in fact they go beyond this—and provide the principle, new in evolution, that food not normal to a given organism may so affect its germ-plasm as to give rise to heritable variations. This being granted, we see at once how a change in habitat can originate new forms, and finally new species. In no group of organisms would this be more potent than in plants. In the variation of cultivated plants influences of the same order are at work. Local races of animals find a ready explanation, and so do the various forms into which wild animals break when domesticated. In plant associations different species grow intermingled, so what more likely than the accidental transference of eggs or larvæ to the wrong food-plant? Is not the difference between species chemical? If larvæ so transferred react as in the experimental work, new phytophagous races or species must arise." This is claimed as experimentally proved for a gall-making saw-fly; and as interpretative of the difference of allied insect species on their distinct food plants.

The range of experiment thus opened will no doubt soon be widely extended; and it will be well worthy of attention on general grounds as bringing the influence of nutritional environment as an evolutionary factor in the origin of varieties and species to more critical and comprehensive testing than ever before. Moreover, in course of such investigations, with their controls, the often-alleged influences of other environmental conditions may also be further tested.

Are there Modificational Species?—For many years in the course of our personal studies the conviction has grown on us that, in certain series of organisms, there are well-defined "species" which differ from one another simply and directly because their environments are slightly different. We call them "modificational" species, meaning that their differentiating features are not hereditary, but are impressed on each successive generation as the direct results of

peculiarities in environment, nutrition, and habits. The suggestion cannot be taken very seriously until it is made the subject of critical and sceptical experiment. Yet the idea should be kept in mind; there are many suggestive facts. Thus we have seen two "species" of Alcyonarians, distinct as regards structure of spicules and individual polyps, growing as members of one and the same arborescent colony, where the conditions are necessarily not quite uniform throughout. In many cases, throughout the animal and vegetable kingdoms, a particular species habitually develops and lives in a specific environment, which perhaps evokes or, it may be, indents particular structural features. Development in a novel environment may in some cases, as in sponges, result in the appearance of very atypical characters, which may be interpreted as somatic modifications. Giard called this "pœcilogony".

Now the question rises whether some of the specific characters which we unhesitatingly regard as intrinsically diagnostic of a species may not be simply somatic modifications, reappearing generation after generation because uniformly reimpressed, yet never as such forming an integral part of the germinal inheritance.

Labbé has made some interesting observations on certain small crustaceans (Canthocamptus) living on the Salines of Croisic. He found that increased hydrogen ion concentration affected the progeny in such a way that it included several species! Thus eggs in the ovisacs of specimens of *Canthocamptus minutus*, exposed in a new medium, developed partly into typical forms, and partly into three other species, one of them new! The non-typical forms he calls "allomorphs". This interesting conclusion has received valuable taxonomic criticism from an expert, Mr. Robert Gurney, who also points out the great risk of the accidental inclusion of the minute larvæ of other species. Nevertheless, it is an idea worth watching!

VARIATION AND HEREDITY

Yet a further word on Variation in relation to Heredity; which have generally been, and still very commonly are, too sharply contrasted. So far, no doubt, these seem antithetic: but we must remember Hegel's law—that no antithesis finds simple and final synthesis, but rather two counter-syntheses, and so far antithetic still, yet complemental too. So in this case, and on one side, variable Heredity, for which the Mendelians have made room; and on the other side hereditary Variability, as in De Vries's conspicuous many and new variations amid his Œnothera sowings. No doubt heredity has been accumulating its brake-power on variation throughout a long past; much as we see in the powerfully

repressive tradition of every old human institution or society; yet (as with that) there may also come a time in the history of a strongly stabilised form of life when at some point it cannot but burst its hereditary bonds; and so may even set out on a more or less contrary line of development: witness that oscillation from floral exaggeration to vegetable predominance already illustrated, as by Asparagus, etc., and even conversely, as with flower-rich weeds, and we mention Masdevallia especially. Much as a young human individual has often to choose between failure and re-adaptation in a changed or new environment, so we see in the importation of new plants, or (say) insects, into a country new to them: for there they either tend to die out, or to grow and propagate more vigorously; indeed, often to veritable pests, thus calling for the use of checks, like the importation of their home enemies, now so frequently called for by agriculturists and foresters. Sometimes the imports show vegetative changes as well, like the immense thickness of watercress stems in New Zealand rivers. Variations from such geographic change may not be fixed within the short period of experiment, like Bonnier's Paris seedlings altered by Alpine environment, yet not retaining this on their return. Yet after all we could hardly expect any other result: but a case like that of ordinary European deciduous peaches and plums becoming evergreen in the climate of Réunion and yet so far keeping true on return to their usual conditions, goes far to show that environmental conditions may bring about more or less transmissible variation, as also do Tower's experiments on the Colorado beetle. Nor can the lines of research undertaken by the unfortunate Kammerer be entirely abandoned.

Returning to Heredity, what does it mean, if not fundamentally continuance of the growth impulse, and its guidance, on abbreviated —that is to say accelerated—lines: so why should this developmental impulse stop? The inheritance of Proteus is like that from Prometheus—not of mere yolk like coals, not mere building-plasm even, but of life, like fire. This is not postulating any mystic power in growth: it is the mechanist who is postulating a sudden hereditary limit to its creativeness; but such arrest is more simply explained by the attainment of maturity enough for reproduction.

In this connection it is interesting to note, as in going through a garden or herbarium, how many species and varieties are essentially definable in terms of the different characters presented by their vegetative system, yet with practically little or no change of flower; as for conspicuous instances among the composites, of which the floral distinctions are so much smaller and subtler than most, whereas, in so many other groups, it is the flowers which present the conspicuous characters, with but little or no apparent variation in foliage and habit. To discriminate the characters of what we may

thus call vegetative species and varieties, from floral ones, and next to scrutinise each of these for their interactions, is a fruitful task, in phanerogamic botany especially: and one finds invitations to attempt the like in the animal world as well. Occasional vegetative "sporting"—as of the purple beech from the green, or of columnar or weeping varieties in other trees—is still unexplained; and the mystery of how a common tulip-bulb may suddenly produce a fine new variety of flower also remains unsolved, despite the many experiments of tulip-growers; and unless our conception, of oscillation of vegetative and floral, explains it?

Variations may also be studied with much advantage as alterations of growth-times; thus may not what we call "reversions" be considered as too early slowings of development? And may not the crossing of different ages, or age-types—as with Mendel's peas, green and yellow, smooth or wrinkled—be of more importance than Mendelians seem to recognise? And may not rates count, as well as ratios, of metabolisms in different regions, or organs? Perhaps even among the so often well-defined and elaborately detailed differences of the sexes throughout plants and animals, as we have so long been urging (*Evolution of Sex*, 1889, and *Sex*, 1914), which arise fundamentally from respective preponderance of Anabolism over Katabolism in the female, and conversely for the male; as breeders and others at length begin to admit. And so, too, for the frequent contrast of allied species or genera as respectively feminoid or masculoid—like bee and wasp, sheep and goat. Is not this also but a more intimate development of the more vegetative or more floral divergence and contrast presented above?

Finally, it is well to bear in mind the important suggestion made by Baldwin, Lloyd Morgan, Osborn and Ward (awkwardly termed "Organic Selection", but for which we have no better name), viz. a reply to the extreme restriction of enduring and heritable variations to the germ-plasm and its genes—that climatic influences, individual modifications, and experimental adaptations may not only count in individual life, but towards evolution, until the corresponding constitutional and germinal variations become established. That such should be independent, and yet coincident, would have too many chances against it; but Weismann would admit that germinal change might, sometimes at least, be coincident; i.e. reached by the same factor as that modifying the parental body. For he did not maintain his germ-plasm to be so completely isolated from influence by or from the parental environment as have some of his later exponents.

Enough, however, if the whole preceding outline-discussion serves to indicate that many and large fields are open to inquiry into the interpretation of variations, and even of the nature and origin of species.

REGISTRATION OF VARIATIONS

If a considerable number of organisms of the same age and sex are examined and measured as regards a particular feature, e.g. stature, length of wing, size of leaf, or number of hairs on a particular area of the body, and if the observed differences are indicated by the height of a series of perpendiculars rising from a horizontal scale indicating amount, a joining of the tips of the perpendiculars yields a line which often becomes more and more of a continuous curve as the number of measurements increases. It is called the curve of frequency, and it is illustrated when results depend on a considerable number of independent conditions. Thus in Galton's apparatus the outline of the pellets dropped through hindrances into subjacent compartments showed this characteristic curve (Fig. 171).

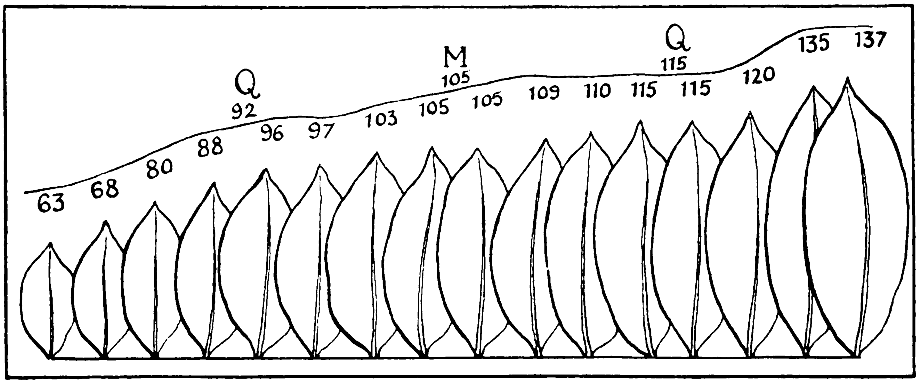


FIG. 170.

An Array of Leaves from the Same Plant, illustrating the observed plus and minus differences in size. From De Vries.

When the lengths of whole organisms of similar age and sex, or the dimensions of particular parts, are thus plotted out, the curve is often symmetrical; there are as many deviations to the right as to the left, but the vast majority are represented by the central perpendicular or by others close to it on either side.

At the one extreme, for instance, there is a small number of marked giants, at the other extreme there is an equal number of marked dwarfs. The more divergent the variations the fewer there are of them. This biometric registration of observed differences is of great value, and it has been elaborated by Galton and Pearson into an intricate technique. Its value increases with the number of data, for conclusions drawn from thousands of observations are obviously much more reliable than those based on hundreds. Much depends also on the homogeneity of the material, thus a quantitative registration, on one curve, of, say, the sizes of organisms of different

ages and sex would tend to fallacy. Similarly in registering "observed differences", which are simply to be measured, it becomes very im-

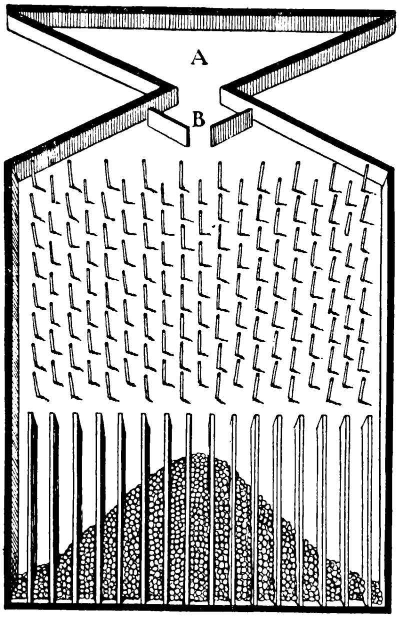


FIG. 171.

Galton's Apparatus to illustrate the formation of a curve of frequency by pellets falling fortuitously through the pegs of the upper part of the box into the compartments beneath. A, the mouth of the apparatus, and B the baffles narrowing the neck.

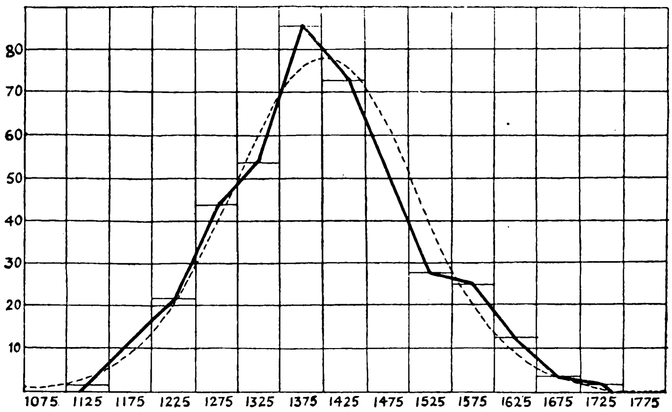


FIG. 172.

Figure to illustrate the curve of frequency so often shown by the variations of a species. From Pearl. The particular curve refers to the brain-weights of adult male Swedes. The basal figures indicate grammes; the vertical figures indicate the number of individuals.

portant to go on to try to distinguish "modifications" (directly due to peculiarities of nurture) from "variations" (outcrops of germinal

disturbances and re-arrangements). It is only when we can definitely subtract from the observed differences all the "modifications" (probably non-transmissible) that we get at the germinal variations which certainly form the greater part, if not the whole, of the raw materials of possible evolution.

Suppose we have registered the occurrence of variations and obtained curves like those in Figs. 171 and 172, a glance at the curve shows the range of variation of the particular species as regards the character measured. A more or less stationary species would show a very symmetrical curve, as many below as above the central mean. A low curve would indicate that there was no very striking difference between the great majority and those at either end, but a curve rising very high at its climax would indicate that there were on either hand numerous individuals diverging from mediocrity.

If the curve that results from registering the measured quantities is very lop-sided, its skewness will show at once that the stock or community measured is evolving in one direction as regards the measured character; and if the same shape of curve is yielded in different places and among different stocks, the inference would be that the species as a whole is moving in a particular direction. Similarly a very marked double-peaked or double-humped curve might serve a useful biological purpose in its statistical registration of the fact that the species was splitting into two species. But we cannot do more than give this faint indication of the value of this very important method.

ARE ACQUIRED GAINS ENTAILED?

All biologists, of whatever school, are agreed that peculiarities of nurture, for better or for worse, may mean much for the individual. Nurture includes all the environmental, nutritional and habitudinal influences, and the individual organism is often profoundly influenced by their generosity or niggardliness, adequacy or inadequacy, normality or abnormality. The degree of development attained by what we may call the hereditary "buds", depends, so to speak, on the soil and the sunshine, the wind and the rain. Recall the Dalmatian newt called Proteus, which remains wan-white in the dark caves, but soon puts on pigment in the well-lighted laboratory. Its buried and arrested eye may develop a little further than usual, if it is illumined.

The red Chinese primrose, familiar in greenhouses, has red flowers when it is reared at 15°–20° C.; but the same plant, reared at 30°–35° C., with moisture and shade, has pure white flowers. There is a Mendelian race of American fruit-flies (Drosophila) with a peculiar abnormality which is exhibited generation after generation

in a moist environment; but if the flies are reared in dry environment —like good Americans—then they are perfectly normal. "Every character", Prof. T. H. Morgan says, "is the realised result of the reaction of hereditary factors with each other and with their environment." With this all biologists agree. It must not be supposed, however, that the influences of surroundings, food and habits always act in a uniform way. Some influences are conditions of normal development; others produce structural novelties (technically called "modifications"); others act as subtle stimuli, tonics or disturbers.

Most of our precise information in regard to the changes produced by peculiarities of nurture relates to individual organisms. We know what increase in weight will be shown by the heart of white rats condemned to take an unusual amount of exercise. We know what

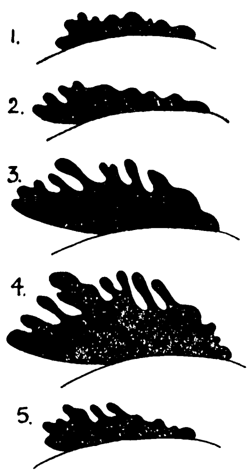


FIG. 173.
Illustrating the Change in the Comb in Poultry under waxing (1–4) and waning (5) hormone-stimulation.

dimensions will be attained by two freshwater snails in three months, if one is reared in a narrow-necked vessel, and the other in a vessel with a large free surface. We know what happens to the retina of goldfishes that are kept for a long time in total darkness; but through lack of energy we do not know whether the offspring would be any the worse of their parents' acquired blindness.

On the other hand, it is known that peculiarities in the nurture of parents may affect the general vigour of the offspring, especially in cases like mammals and flowering plants where the offspring remain for a considerable time sharing in the life of the parent organism. In a few cases, for instance, it has been shown that the germ-cells may be prejudicially affected by some poison which is saturating through the body of the parent. No one, not even Weismann, has denied that the offspring may be influenced in a general way, for better or for worse, by deep changes in the chemical

routine or metabolism of the parent. In a few cases the subtle quality of immunity, acquired by a mammalian mother, may be exhibited by the offspring; but this is probably due to the interchanges that go on between mother and offspring during the intimate symbiosis of ante-natal life.

The question, that remains open, is the familiar one, not very

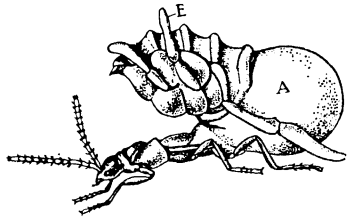


FIG. 174.

The Strange State of "Physogastry" in the Guest of an Ant. A, the bloated abdomen; E, the tube of a gland secreting an acceptable exudation. After Wheeler.

happily expressed in the words: "Are individually acquired characters transmissible?" Perhaps this is better: Can a structural change in the body, induced by some new peculiarity in use or disuse, or in diet, or in surrounding influences, affect the germ cells in such a specific or representative way that the offspring will, through its inheritance, exhibit, even in a slight degree, the modification which the parent acquired? A good term for an "acquired character", in

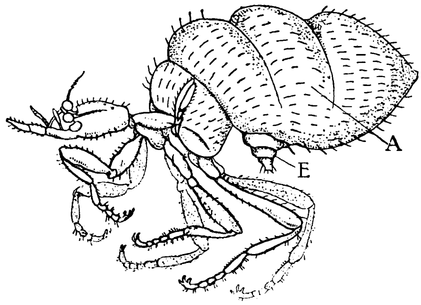


FIG. 175.

Deformed "Physogastric" Guest of an Ant. A, abdomen, much swollen; E, duct of gland. After Wheeler.

the sense of the Spencer-Weismann controversy, is a "bodily modification", or an "exogenous somatic modification". These modifications are common; the question is whether they are ever hereditarily transmitted from parents to offspring—hereditarily entailed in a specific and representative way? Was Lamarck right, was Darwin right, in answering this question in the affirmative? For it should be noted that while Darwin attached only a secondary importance

to the transmission of parentally acquired characteristics, to which Lamarck attached a much greater importance, he explicitly accepted the possibility. To Lamarck the raw materials of evolution seemed in the main "modifications" (exogenous); to Darwin the raw materials of evolution seemed in the main "variations", arising, he knew not how, *from within*.

Everyone must welcome recent work bearing on the transmissibility of modifications, and such convinced statements of the affirmative position as Prof. MacBride has given us. But there is great need for caution, and it may be of interest to refer to two or three pieces of evidence, which show the difficulty of getting a clear-cut result, admitting of the Lamarckian interpretation and of no other.

Return to Stockard's thirteen years of experiments with guinea-pigs which he treated with fumes of alcohol. Over 5,000 animals were used, and several were treated for as long as six years. Some of the treated animals lived for over seven years, probably the longest life span recorded for guinea-pigs. The fumes did not injure or noticeably modify the structure or behaviour of the treated animals. "But while the parents lived long and well, their descendants showed a high early mortality and were structurally defective in many cases." Is this evidence of the transmission of acquired characters? This is not Prof. Stockard's view, for he thinks that the alcoholic poison saturating through the body of the treated parent affected the germ cells prejudicially, so that they subsequently gave rise to low grade or arrested offspring. The weak and defective offspring and later descendants of the alcoholic guinea-pigs never showed any "new character" or any exact condition that was acquired by the parents or progenitors as the result of the inhaling treatment. This is only one out of several similar experiments; it serves to illustrate the need for critical caution. Others, moreover, have failed to confirm his results.

Doctors Bentley and Griffith in Philadelphia rotated rats at speeds of 60–120 revolutions per minute and kept it up for 2–18 months. The rats fed and bred, played and slept in their revolving cages. When they were liberated, some fell into a decline and died, others exhibited, sooner or later, marked disturbances in their locomotion and eye movements. Some of them were paired with normal rats, and the offspring showed a high proportion of "disequilibrated" individuals. This looks very like the handing on of a specific disturbance, and *this may be the correct interpretation*. But Dr. Detlefsen has put his finger on a possible fallacy. The whirling may have set up inflammatory processes in the inner ear; there were often discharges from the ears of the rotated rats; and it may be that there is an associated pathogenic microbe which might pass, by contact, for instance, from parent to offspring. Dr. Detlefsen studied twenty cases of "spontaneous" ear inflammation among

non-rotated rats, and these showed the two kinds of locomotor disorder that marked the rotated rats and their offspring according to the direction of the whirling, whether clockwise or counter clockwise! Dr. Detlefsen does not set himself to explain away the results of the experiments made by Drs. Bentley and Griffith; he merely indicates a possible fallacy. And that is sound science.

One other instance must suffice, for our present point is simply to illustrate the difficulty of getting a clear issue. Prof. M. F. Guyer and Dr. E. A. Smith injected into fowls a salt solution of pulped rabbit-lens, to which the blood-serum of the fowl reacted, developing lens-antibodies—that is to say, counteractives to the intruded substance. Some of the fowl-serum was then injected into female rabbits with young. Of the sixty-one surviving offspring of these rabbits four had one or both eyes conspicuously defective, especially as regards the lens, and five others had eyes that were clearly abnormal. The lens-antibodies in the blood produced specific eye-defects in the embryos—defects which no other mode of treatment ever produced. But the striking fact is that once the defect has arisen, it may be transmitted to subsequent generations (as many as nine) through breeding. The descent has been repeatedly established through male as well as female lines. The abnormal condition has in general the characteristics of a Mendelian recessive; i.e. a defective-eyed rabbit bred to a normal-eyed rabbit has only normal-eyed progeny in the first generation.

Here then is a very remarkable case. Developing embryos were specifically modified in their early ante-natal life by the influence of an antibody introduced into their parent's blood, and this specific modification was handed on to subsequent generations, and by males as well as by females. It may be, however, as Prof. Guyer points out, that the germ-cells of the original offspring were specifically affected at the same time as the eyes, and that the lens-producing constituents in these germ-cells were specifically damaged. This would be what is technically called "parallel induction" rather than the transmission of a somatic modification. It is interesting to find that the eye-defects may increase from generation to generation, which looks as if the deteriorated eye could originate chemical substances in the blood which repercuss deterioratively on the germ-cells. In any case, it is clear that the germ-cells do not live a charmed life, uninfluenced by the turmoils that may be set up in the body.

Some of the recent experiments, such as Kammerer's, seem to us to suggest an affirmative answer; others, such as Agar's, seem to us to suggest a negative answer; none seem to us to be definitely conclusive—not even Kammerer's until more details are forthcoming. Why should we hurry, except for more facts? We should not like to be responsible for Herbert Spencer's two alternatives—"either there has been inheritance of acquired characters, or there

has been no evolution". That was surely a bad lapse from scientific method!

THE ISOLATION OF GERM-CELLS.—Granting all that is reasonably said as to this, it must not be made too much of, as if these were like

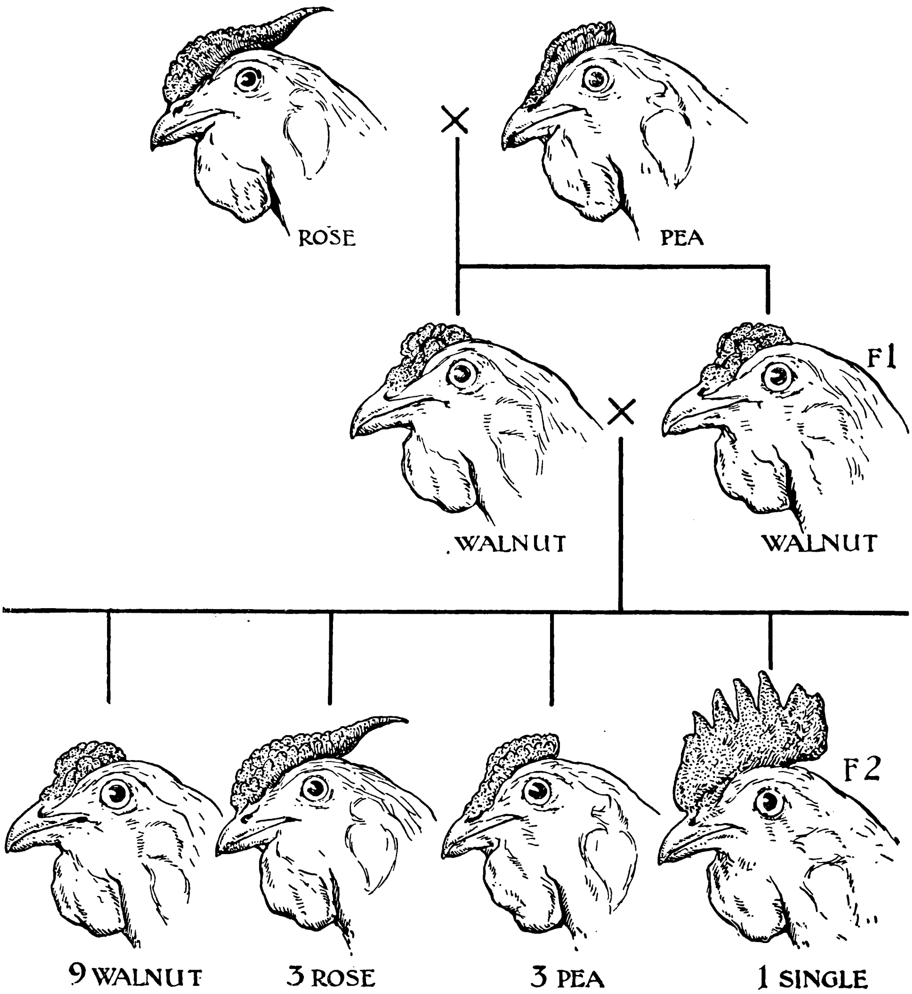


FIG. 176.

Combs in Poultry, illustrating Mendelian inheritance. From a specimen. A cross between rose-comb and pea-comb yields walnut combs (first filial generation, F1). If these are inbred, the second filial generation (F2) shows walnut, rose, pea, and single combs in the proportion 9 : 3 : 3 : 1, which is characteristic of dihybridism, when the original parents differ in two pairs of contrasted characters or allelomorphs.

the precise and precious standards of our weights and measures which must be kept protected from the ordinary usages of life. For with all their individuality, can the germ-cells avoid being influenced by the body which not only contains but maintains them before and up to their maturation to functional life, and in mammals

throughout their main development also? Since their development, maturation, and decline so markedly determine the main phases of development of the body, must not the body's growth and development in some measure affect them in turn? The gonads which produce these cells contribute important hormones to the body, and towards its phasal changes; and the body's hormones in its circulation cannot but in some measure reach these; so why not influence them too? And as the importance of neural and psychic tone is appreciated throughout the physiology of health and disease alike, and by all schools of medicine however otherwise differing, since of the very maintenance as well as recovery of health, can gonads and germ-cells be conceived as lying wholly outside such influences? And since each germ-cell carries with it the psychic heredity of its species, continued from that of its real parents of the previous generation, can it be wholly insensible to the psychic states, as affecting neural tonus of the body which has so long nourished and borne it? Since its maturation and emergence to fertilisation raises the bodily and even the psychic life to ever-increasing intensities, even to orgasms in which culminate the ecstasies and agonies of life, can it be wholly independent and unmodifiable, and at what is also its own life-crisis? Important though be our anatomic and histologic knowledge, may not love's unions have more in them than we know? And in the strangely mingled and glowing witchpot of each individual life, how can its germs escape being deeply dyed?

We cannot as yet answer any of these questions—which would involve subtleties of research beyond all ordinary ones: yet they are suggested as tending to keep open outlooks and towards possibilities which various elements of the very progress of knowledge which we have been appreciating have sometimes been too apt to close.

NATURAL SELECTION OR NATURE'S SIFTING

A strange irresponsibility of judgment among naturalists is indicated by the frequent swing of the pendulum away from the Darwinian theory of natural selection as a *vera causa* in organic evolution. Because we are beginning to know a little more about the raw materials of evolution—the germinal changes that find expression as bodily fluctuations and mutations—must we leap to the conclusion that there is no need for natural selection? Because we have a little more light than Darwin had on the originative factors in organic evolution, must we swing to the exaggerated view that directive factors or eliminating factors do not exist or do not count?

No one has contributed more than Hugo de Vries to our knowledge of variations, and no one has more firmly indicated the limitations

of the natural selection factor—the pruning hook of the growing and varying *arbor vitæ*. But while we find him approving of the neat criticism: "Natural selection may explain the survival of the fittest, but it does not explain their arrival", we should also notice his broadminded attitude to the central theory of Darwinism, as in the sentence: "Variations may arise slowly, from simple fluctuations, or suddenly, by mutations; in both cases natural selection will take hold of them, will multiply them if they are beneficial, and in the course of time accumulate them, so as to produce that great diversity of organic life, which we so highly admire." Yet many too readily accept psychologically warped asseverations to the effect that natural selection is not of much importance in evolution. In saying "psychologically warped" we allude to the familiar vice of experts who, having discerned some one factor with intense vividness, let us say Mendelian inheritance, are thereby impelled to depreciate every other factor. But because one happens to have had a revelation of Brahma the creator (giving origin to mutations), one does not feel it necessary to deny the power of Kali the destroyer (natural selection, in fact).

Therefore, while we do not wish to appeal to authority, we would quote De Vries again, for he has done so much in the way of illuminating investigation. What does he say in the Darwin Centenary essays? "The origin of new species, which is in part the effect of mutability, is, however, due mainly to natural selection. Mutability provides the new characters and new elementary species. Natural selection, on the other hand, decides what is to live and what is to die." Here there is nothing but clearheadedness in regard to the difference between originative and directive (or sifting) factors.

It is useful now and again to point out that a sieve does not make what it sifts, and that the pruning shears do not exactly cause the tree to grow; and its reiteration was provoked by too exclusive insistence on "the All-Sufficiency of Natural Selection". It was quite useful for Samuel Butler to gibe in his inimitable fashion at the extremest Darwinism (beyond Darwin): "It does not explain to me how I came here, that my uncles and aunts went away." But such a witty jest has much more justification than Driesch's: "Darwinism . . . explained how, by throwing stones, one could build a house of typical style."

It is a pity that people who sway public opinion on difficult questions do not read a little more before they make their deliverances. Thus in very few recent evolutionist discussions have we seen anything that would lead us to suppose that the disputant had taken account of such an important investigation as Baur's study of snapdragons (Antirrhinum), in which it is shown, after many years of research, that the garden races are constantly exhibiting small mutations, transmissible in their entirety in

Mendelian fashion, often going one better than the parents, and occurring copiously even in "pure lines", that is to say, in lineages all descended from one. As to the wild species of snapdragon, Baur has come to the conclusion that they have been and are in many cases the result of the summation of small mutations comparable to those that are of everyday occurrence in the garden. In natural conditions, he says, the summation may be put to the credit of Natural Selection, which sifted and sifts the mutations in reference to the diverse and changeful conditions of locality and climate. Large mutations he recognises as also occurring in cultivated races

FIG. 177.
Two Mutants (A and B) of the Evening Primrose (*Œnothera lamarckiana*). After De Vries.

of snapdragon, and on these, apt to be extreme, the gardener operates in his Artificial Selection. His sieve is large enough, so to speak, to let pass some mutations which Natural Selection might sift away. So we substantially come back to Darwin's own Darwinism!

Since Darwin's day the effective operation of Natural Selection has been repeatedly demonstrated, e.g. by Weldon, Crampton, Poulton, and Cesnola. Why, then, has there been this reaction from the theory? Largely because so few think resolutely, or are able to withstand being blown about by every wind of doctrine. Let us consider briefly the three most important objections that have been brought against Darwin's view.

(1) If mutations have been common throughout the evolution-

process, if a new position of organic stability has often been reached brusquely, if the Proteus has frequently been leaping, marching, or swinging, as well as vaguely feeling its way in creeping—in short, if there be in *Natura naturans* also something of *Natura saltatrix*—then what is required of the theory of Natural Selection will certainly be less than Darwin supposed. Yet we do not find De Vries or Baur jettisoning the theory; and we might give many other examples of active investigators who remain natural selectionists also, not slavishly, of course, but utilising its essential idea.

(2) Of great importance is Johannsen's evidence that if the descendants of an individual high-class bean-plant are kept apart in a pure line, no amount of selection will get beyond the mean of the line. There are indeed some tall plants and some short plants, and other "fluctuations"; but there is nothing to choose between the descendants of the talls and the descendants of the shorts. The reason for this may be that the "fluctuations" in *this* case are non-transmissible "modifications" or "acquired characters" due to peculiarities in individual nurture. There is no use trying to select from amidst non-heritable characters.

But there are other reasons why we must not be swept away by Johannsen's important evidence. It must be allowed, for instance, that "pure lines" are not typical of wild stocks in natural conditions, where cross-fertilisation is frequent; it is dangerous to argue from brief pure-line experiments to the age-long processes of Nature; it is premature to deny the possibility of heritable mutations occurring in pure lines—very premature, since Baur has shown that they may be common.

(3) No doubt it is not always easy to see how a small new departure could persist while still very incipient, too minute to be caught by the meshes of the natural selection sieve. But it seems hardly playing the game to ignore the fact that Darwin, with his usual self-criticism and anticipation of difficulties, gave careful consideration to this very point. He laid stress on "the Correlation of Variations", one being somehow linked to another; and he even suggested, as Romanes and others have since done more fully, that the selection of advances in a major variation might bring the minor variation through the incipient stages until it also was gripped. It must also be noted that a new departure may occur simultaneously in many variants; and if these are segregated, as by any of the many forms of isolation, then the likelihood of the novelty being lost is greatly diminished. Nowadays, of course, that difficulty does not press if the mutation in question "mendelises"; for in that case, if it comes, it comes to stay. And again, when we think of such difficult problems as the evolution of the eye or the ear, it is a familiar reflection that for ages the selection may have been in reference to a function or significance different from that which is characteristic of the

final result. Thus the eye was primarily a light-and-shade organ, not for image-forming; and the ear was for ages an equilibrating organ before it had become a hearing ear.

And as we re-read Darwin we cannot but appreciate his extraordinary realisation of the subtlety of Natural Selection, a subtlety of which, in his humility, he said that he did not always find it easy to keep it in mind. Nature's sifting operates in relation to a very intricate web of life; her winnowing may detect a nuance; an organism that says Shibboleth may have survival value as against one that says Sibboleth.

Yet when it is asked how the System of Animate Nature has come to be, the answer is frankly that we require Brahma the creator as well as Kali the destroyer. Darwin postulated the Proteus, admitting that its quick changes were beyond him.

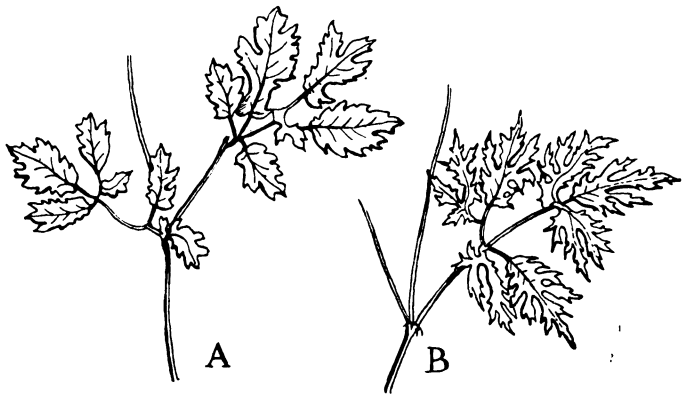


FIG. 178.
Two Variations (A and B) in the Foliage of the Same Species of Geranium.

"What the devil", he said, "determines each particular variation?" Thanks to Bateson, De Vries, and many others, we know much more about variations than Darwin did; thanks to Mendel, and Weismann, and many others, we know much more about the laws of their entailment than Darwin did; but we are mostly lagging seriously behind Darwin in the development of the doctrine of Selection. "Evolution", as Graham Kerr recently said, "is a philosophy of wild nature"; and it is when we envisage organisms in their natural surroundings that we realise the evolution of sieves as well as the evolution of the material to be sifted. Linkages established in the System of Nature operate on the whole against retrogression and towards advance. No doubt the tapeworm is the outcome of evolution as well as the Golden Eagle, for fitness is relative to the particular conditions of each life; yet on the whole the emergence of the Golden Eagle is more typical of the evolutionary process, which is *integrative* at the core. We do not doubt that Natural Selection sometimes puts on a brake, even on variability;

but in other cases it acts as an accelerator of progress, and it operates in relation to an established System of Nature *which becomes increasingly complex.* Our point is that while the varying organism may be in itself progressive, the converse of a radio-active element, the sieves may also work in the same integrative direction.

SIFTING IN THE HIMALAYAN JUNGLE.—It is always desirable to pass from general discussion to concrete case; and we venture to do this abruptly here, to remind the student that the issue, always one of life and death, sometimes very literally, involves a mortal fray. We have known of two hundred small birds being killed in a single night in a single stack-yard by an unusually hard frost; but such life-or-death modes of the struggle for existence have in temperate countries a very moderate occurrence compared with what happens in the tropics. In Mr. William Beebe's *Pheasant Jungles* (Putnam's, 1927) we get some glimpses of the frequently terrible severity of the sifting. He was on the track of pheasants, on which he is the greatest authority, in the jungle of Kinchinjunga, when, without warning, there suddenly descended a terrific burst of hail. The foliage and moss were torn to shreds as by shot. The ferns were lashed flat. "In a very short time the pellets of ice were piled up three to five inches, and untold numbers of forest creatures must have perished miserably." Two nests that Mr. Beebe had been watching were beaten from their supports and their contents crushed. "Every blossom was in shreds, not a leaf remained whole, and the forest, from the peace and warmth and life of the full flush of spring, took on the death-like aspect of winter. Such storms kill dogs, fowls, geese, cattle, and even men; and the destruction of pheasants and their eggs and young must be enormous."

It is probably true that such very severe natural elimination is of less importance in evolution than the more moderate sifting that we are familiar with in the southern parts of north temperate countries, for there is very little chance of an organism reacting effectively to a cruel hailstorm such as Mr. Beebe describes with his wonted vividness. Mere reduction of numbers is not of much value as a factor in evolution; it is discriminate selection that counts. The only real sifting effected by the hailstorm would be between those animals that are quick, and those that are slow to find shelter. In less extreme countries we see the sifting at work, quietly and unsensationally, in every hedgerow and shore-pool.

SEXUAL SELECTION

Darwin's theory of Sexual Selection is no longer wholly acceptable in the form in which he stated it, but modern criticism has erred

in over-destructiveness. In regard to some of the questions involved, the wisest course is probably to suspend judgment until fresh facts, especially of an experimental kind, accumulate. In regard to some other implications, however, it seems possible to meet some of the chief objections by a re-statement in the light of new data.

It was primarily in reference to secondary sex-characters that Darwin suggested his theory of sexual selection. Certain variations, e.g. in the improvement of weapons and food-catching apparatus, are favoured by natural selection in the course of the everyday struggle for existence; in the same way, variations which are advantageous in securing mates and consummating sexual reproduction will be favoured by sexual selection.

Darwin began with instances of the importance of masculine vigour and equipment when rival males compete for the possession of the females. "The strongest, and with some species the best-armed of the males, drive away the weaker; and the former would then unite with the more vigorous and better-nourished females, because they are the first to breed. Such vigorous pairs would surely rear a larger number of offspring than the retarded females, which would be compelled to unite with the conquered and less powerful males, supposing the sexes to be numerically equal; and this is all that is wanted to add, in the course of successive generations, to the size, strength, and courage of the males, or to improve their weapons." (*Descent of Man*, 2nd ed., 1888, vol. i, p. 329.)

Now it is plain that forceful competition among rival males for the possession of a female or of several females, does not differ in kind from the ordinary struggle for food and foothold, except that it is strictly intra-specific. Darwin pointed out indeed (p. 349) that sexual selection is less rigorous than natural selection; that it is less of a life-and-death affair; that it operates through the unsuccessful males having fewer, less vigorous, or no offspring; and that it is not limited by the general conditions of life; but there is in all this no departure from the general logic of the theory of natural selection. This part of the theory, therefore, remains valid to those who regard natural selection as a *vera causa*.

Darwin went on to those characters that are useful in the recognition and capture of the females. When a male excels his neighbours in his capacities for finding, pursuing, and catching the female, sexual selection, he said, again comes into action. (*Descent of Man*, p. 324.) The male moth often finds his mate by the olfactory acuteness of his large antennæ; some small crustaceans recognise the other sex almost instantaneously when there is chance contact in the water; in some fishes, recognition depends on colour and on behaviour; many experiments led Goltz to believe that the male frog distinguishes the female by touch; in birds, visual and auditory impressions count for most; in mammals, the scent is often of chief

importance. (See S. J. Holmes, *Studies in Animal Behaviour*, Boston, 1916, pp. 219–328.)

Since correct recognition of the one sex by the other is often of essential importance to the race, it is not surprising to find Darwin saying (*Descent of Man*, p. 324): "But in most cases of this kind it is impossible to distinguish between the effects of natural and sexual selection." This part of the theory also remains valid to those who believe at all in the evolutionary efficacy of selection.

Darwin primarily used the term sexual selection for all cases where sifting occurs in relation not to ordinary food-getting and self-preservation, but to pairing. It was only secondarily that he laid emphasis on the "choice" that the female is supposed to exercise in reference to rival suitors. An interesting confusion, which has misled some biologists, has arisen by a double use of the word selection. Darwin spoke of the female's selection, but it is perfectly clear that he recognised a large field of sexual selection in which there was no question of selection or choice on the part of the female. (See *Descent of Man*, 2nd ed., 1888, vol. i, p. 323, footnote.) Sexual selection meant, for Darwin, sifting in connection with mating, whether the female held the sieve or not.

In his next step Darwin used the word selection in a *non-metaphorical* sense: "Just as man can give beauty, according to his standard of taste, to his male poultry, or more strictly can modify the beauty originally acquired by the parent species, . . . so it appears that female birds in a state of nature, have by a long selection of the more attractive males, added to their beauty or other attractive qualities." (*Descent of Man*, 2nd ed., 1888, vol. i, p. 326.)

In many animals, at diverse levels of organisation, there is an elaborate courtship-ceremonial, allied, according to Groos, to play. It is sometimes on both sides; it is usually for the most part on the male's side. It includes a manifold display of decorations, colours, agility, and vocal powers. Darwin's theory in this connection was simply this: if there are rival males, and if they are unequally endowed with structural and emotional equipment, or with the capacity of using this to advantage, there will be preferential mating on the female's part, and, other things equal, there will be a selection of the type of male most successful as a suitor. It is the female who sifts, but the logic of the process is the same as in ordinary natural selection.

It is conceivable that pronounced and persistent differential mating might lead not merely to the establishment and augmentation of characters determining the result of the contest or the courtship, but also to a process of physiological and psychological "isolation" (narrowing of the range of intercrossing), and thus to an accentuation of the apartness of a species as regards crossing

with related neighbour-species. (See Karl Pearson, *Grammar of Science*, 2nd ed., 1900, p. 418.)

At this point attention may be directed to the important contributions to the Natural History of mating to be found in H. Eliot Howard's monumental *British Warblers* (1907–15). We venture to think that this acute and sympathetic observer exaggerates what most naturalists call the "instinctive" at the expense of the "intelligent" element in the behaviour of birds, and that he is unnecessarily antagonistic to Darwin's theory of sexual selection, but his work is a rich treasure-house of reliable data. It is of great interest, for instance, to realise how much competition there is among the male warblers, before the females arrive on the scene, in the way of discovering and securely holding the most advantageous, or, to the several individuals, most pleasing "territories" for nesting. Not less important is the evidence that the soberly coloured warblers do not fall behind brilliantly coloured birds in the elaborateness and abandon of their display attitudes and poses. We have referred in the section on courtship to Howard's observations and reflections on the courting behaviour of such birds as the yellow-hammer.

CRITICISMS OF DARWIN'S THEORY OF SEX SELECTION.

Darwin was well aware of many of the difficulties besetting his theory. With his wonted candour he anticipated various objections, e.g. that the theory "implies powers of discrimination and taste on the part of the female which at first appear extremely improbable". (*Descent of Man*, p. 326.) The first very serious criticism came from Wallace in 1871, and was restated in his *Darwinism* in 1889. The most elaborate criticism as yet is surely to be found in T. H. Morgan's *Evolution and Adaptation* (1903), where no fewer than twenty-four reasons are given for rejecting the theory. Within our narrow limits we must confine our attention to the three criticisms which seem most important.

(*a*) There is, in the first place, an admitted difficulty in the scarcity of direct evidence that some of the males are actually disqualified and left unmated. If all the males get mates sooner or later, then no discriminate elimination is effected. Prof. Karl Pearson has given statistical evidence of preferential mating in mankind, but this is hardly procurable in the animal world. Darwin met the objection in various ways. He pointed out that in some species the males outnumber the females, and that in some other species there is polygamy. If the more attractive males have in such cases an advantage in mating, the direction of evolutionary movement will be determined by them, and not by the handicapped

residue of the unattractive. He also pointed out that the more vigorous and more attractive males would be accepted by the more vigorous females which are the first to breed, and this would imply a cumulative preponderance of the more vigorous and more attractive types. Even earlier hatching of the young birds might be of critical moment.

As a matter of fact, definite information as to the elimination of some of the males is by no means wholly lacking. Thus in diagrammatic illustration we may refer to some spiders where, as the Peckhams and others have shown, the female sometimes kills a suitor who does not adequately please her. That she may also kill a successful suitor is immaterial, since the mating has been accomplished. (See G. W. and E. G. Peckham, *Observations of Sexual Selection in Spiders of the Family Attidæ*, Milwaukee, 1889, p. 60.) It has been pointed out, however, that this devouring of the male is exceptional, yet it is interesting to notice that where it does occur, it is often because the male has failed to conform to the frequently very subtle "rules "of sex-behaviour!

(*b*) In the second place, many critics have objected to crediting the female organism—whether bird or butterfly—with the power of "choice", and while comparative psychology has not advanced far enough to admit of many definite statements as to the subjective aspect of animal courtship, it may be granted that there is not in the "choice" of any female animal much that would correspond to a human weighing of pros and cons. But the point of importance is whether the mating is *in any real way* selective, preferential, discriminative. It has been proved experimentally that insects as well as birds may be selective in their eating: is the same true as regards their mating? It appears to us that the phenomena of mating recorded by Darwin, by Groos (*Play of Animals*, 1898), by Cunningham (*Sexual Dimorphism*, 1900), by Pycraft (*Courtship of Animals*, 1913), and so on, place the reality of some measure of preferential mating beyond doubt. Even if one adopts the modern view that the female does not choose the "best" out of a bunch of suitors, but rather remains unresponsive to the solicitations of males who do not raise her emotional interest to the requisite pitch, that is quite enough for the purposes of the theory; and it is in agreement with Darwin's own remark about the female bird: "it is not probable that she consciously deliberates: but she is most excited or attracted by the most beautiful, or melodious, or gallant males".

(*c*) A third objection is more serious. It is one thing to admit the reality of a somewhat vague preferential mating, it is quite another thing to credit the female animal with a capacity for appreciating slight differences in decorativeness or musical talent or lithesomeness. Wallace's statement of this objection is well known. Referring to Darwin's four chapters in *The Descent of Man*, he says:

"Any one who reads these most interesting chapters will admit that the fact of display is demonstrated; and it may also be admitted, as highly probable, that the female is pleased or excited by the display. But it by no means follows that slight differences in the shape, pattern, or colours of the ornamental plumes are what lead a female to give the preference to one male over another; still less that all the females of a species, or the great majority of them, over a wide area of country, and for many successive generations, prefer exactly the same modification of the colour or ornament." (*Darwinism*, 1899, p. 285.)

But the edge has been taken off this objection by Lloyd Morgan and others, who point out the gratuitousness of crediting the hen bird with a standard of taste or capacity for esthetic valuation. "The chick selects the worm that excites the strongest impulse to pick it up and eat it. So, too, the hen selects that mate which by his song or otherwise excites in greatest degree the mating impulse. Stripped of all its unnecessary esthetic surplusage, the hypothesis of sexual selection suggests that the accepted mate is the one that most strongly evokes the pairing instinct." (*Habit and Instinct*, 1896, p. 217.)

It may be insisted, however, that if individual excellence in attractive characters (such as plumes, singing power, dancing agility) does not as such appeal to the female, it cannot be determinative in preferential mating, and therefore its establishment cannot be effected by any process of sexual selection. Unless the female is *somehow* aware of the individual variation in question, the theory breaks down; and yet it is difficult to believe that the female is so meticulous in fastidiousness, so detailed in her preferential excitability.

The answer, probably sound, is that the details count, *not as such*, but as contributory to a general impression. Each has its effect, but synthetically, not analytically. "Even when the female seems to choose some slight improvement in colour or song or dance, the probability is that she is simply surrendering herself to the male whose *tout ensemble* has most successfully excited her sexual interest." (Geddes and Thomson, *Evolution*, 1911, p. 172.)

UTILITY OF COURTSHIP.—If we provisionally accept the theory that a secondary sex-character may have been established and augmented because it contributed to a decision in preferential mating, we have to face the further question of the significance or racial justification of the courtship-habits—often so prolonged, elaborate, and exhausting. The sifting probably works well in keeping up a standard of racial fitness, for the most persuasive male is likely to be, among animals, the fittest all round. But there is surely more than this.

To Groos and to Julian S. Huxley we owe two luminous suggestions. In his *Play of Animals* (Eng. Trans. 1898, p. 242), Groos suggests that " in order to preserve the species the discharge of the sexual function must be rendered difficult, since the impulse to it is so powerful that without some such arrest it might easily become prejudicial to that end". "This very strength of impulse is itself necessary to the preservation of the species; but, on the other hand, dams must be opposed to the impetuous stream, lest the impulse expend itself before it is made effectual, or the mothers of the race be robbed of their strength, to the detriment of their offspring." . . . "The most important factor in maintaining this necessary check is the coyness of the female; coquetry is the conflict between natural impulse and coyness, and the male's part is to overcome the latter." (Op. cit., p. 243.)

Not less interesting is the suggestion developed by Julian S. Huxley in his remarkable study of the courtship-habits of the Great Crested Grebe, *Podiceps cristatus.* (*Proc. Zool. Soc. London,* 1914, pp. 491–562.) In the Great Crested Grebe the two sexes are practically alike in plumage, colour, and habits; but the courtship is extraordinarily elaborate—a self-exhausting ritual, "not leading up to or connected with coition". Huxley believes that "the courtship ceremonies serve to keep the two birds of a pair together, and to keep them constant to each other". "Birds have obviously got to a pitch where their psychological states play an important part in their lives. Thus, if a method is to be devised for keeping two birds together, provision will have to be made for an interplay of consciousness or emotion between them." The courtship is justified by the strength of the emotional bond it establishes. There is a "Mutual Selection" which is in a way "a blend between Sexual and Natural Selection".

No naturalist has studied a courtship with more thoroughness than Julian Huxley shows in his account of the Great Crested Grebe, and what is his verdict? "Display and ornament do not act on the esthetic sense of the female, but on her emotional state; they are—using the words in no narrow or unpleasant sense—excitants, aphrodisiacs, serving to raise the female into that state of exaltation and emotion when alone she will be ready to pair." " . . . But the element of choice does, in another form, remain. In animals such as Birds, where there is a regular pairing-up season, and where, too, the mental processes are already of considerable complexity, it is impossible to doubt but that mating may be, and in some species is, guided by impulse, unanalysable fancies, individual predilection."

A survey of recent observations on mating, such as is afforded by W. P. Pycraft's admirable *Courtship of Animals* (1913), leaves in the mind a vivid impression of intricacy and subtlety. We agree

with the author in feeling the necessity for psychological as well as physiological interpretation.

HEREDITY AND SEX-CHARACTERS.—The inheritance of secondary sex characters has become clearer since Darwin's day. He was indeed convinced that the secondary sex characters, though expressed in the male or in the female only, are genetically present in both sexes and are transmitted through both. He referred, for instance, to the expression of masculine characters in old or diseased females. But in default of any knowledge of the rôle of internal secretions, Darwin was forced to subsidiary hypotheses. There is an antique ring in sentences like this: "When variations occur late in life in one sex, and are transmitted to the same sex at the same age, the other sex and the young are left unmodified." (*Descent of Man* 2nd ed., 1888, vol. i, p. 371.)

What is indicated by modern experiments in castration, implantation, injection of hormones, as well as in hybridisation, is briefly this, that a positive masculine character normally develops in the somatic milieu of the male, but remains latent in the somatic milieu of the female. It is either inhibited by the ovarian hormones, or modified by these so that it finds feminine not masculine expression. That the masculine character may be potentially present in completeness, is shown by the change in the plumage of ovariotomised young females at the next moult. "If the ovary of a domestic bird be removed completely, many of the secondary sexual characters of the male appear. Some individuals become nearly complete replicas of the male, others imperfect imitations of the male. If the testes be removed, the majority of the secondary sexual characters of the male develop, though a few remain in an infantile condition. Castrated drakes lose the power of developing the summer plumage." (H. D. Goodale, *Gonadectomy in Relation to the Secondary Sexual Characters of some Domestic Birds*, Carnegie Institution of Washington. Publication No. 243, 1916, p. 51.)

The conditions differ in different types; thus Geoffrey Smith showed that the parasitic castration of male crabs of various kinds by Rhizocephala may be followed by remarkable changes in the somatic metabolism, as the altered composition of the blood shows. Thereafter, a small ovary appears and forms ova, the abdomen and its appendages put on feminine characters, and the male carries its protruding parasite as if it were a bunch of eggs. While there are cases of organisms which carry the factors of only masculine or only feminine characters, there are certainly many cases, such as the female bird or the male crab, where there is the potentiality of some of the distinctive characters of the opposite sex. And these latent characters may be activated by a change in the internal

secretions or hormones, or by some other disturbance of the normal routine of metabolism.

SEX AND EVOLUTION.—The establishment of sexual reproduction had many more or less immediate rewards: it meant more economical means of continuing the race; it was a device for securing the persistence of a successful genetic constitution and for screening the offspring from disadvantageous dints made on the parent's body; it implied more opportunities for rearrangements of the hereditary items at the beginning of each new life. The separation of sperm-producers (or males) and egg-producers (or females), differing deeply in constitution, would also tend to increase the possible range of cross-fertilisation, which is often advantageous, and would permit of a profitable division of labour between the two parents in their relations to the offspring; and so on. But in the course of ages the sex-divergence attained another justification; it became the basis of love, it served as a liberator and educator of emotions which have enriched and ennobled the lives of many creatures. As Darwin clearly recognised, characters which were primarily selected in relation to mating, might become secondarily diverted by a function-change to even wider issues.

In his *Studies in Animal Behaviour* (1916), Mr. S. J. Holmes has an interesting chapter on "the rôle of sex in the evolution of mind". "The primary function of the vocal apparatus of the Vertebrates was probably to furnish a sex call, as is now its exclusive function in the Amphibia. Only later and secondarily did the voice come to be employed in protecting and fostering the young, and as a means of social communication. And the evolution of the voice in Vertebrates doubtless influenced to a marked degree the evolution of the sense of hearing. It is not improbable, therefore, that the evolution of the voice, with all its tremendous consequences in regard to the evolution of mind, is an outgrowth of the differentiation of sex." There can be little doubt that the biology of the future will attach not less but more importance to sexual selection. For it seems likely that characters and qualities originally established in this way have often influenced both body and behaviour in reaches now more or less remote from the tides of sex-impulses.

In regard to sexual selection in mankind, four remarks may perhaps be permitted. (*a*) The careful selection of attractive wives, under what we may call the patriarchal regime, has probably been contributory to the evolution of the beauty of women in certain selected stocks. (*b*) Conversely, a restriction of the range of choice in isolated regions and among people with few opportunities of changing their social environment, even for a short time, has probably been, in the absence of a contrary tradition, contributory to the evolution of commonplaceness. Many facts of life point to

the conclusion that marriage without "falling in love" is prejudicial to the race as well as to the individuals immediately concerned. (*c*) The increasing proportion of unmarried women in many civilised communities is one of the serious problems of to-day. The outlook will be even more grave if it be true (this we do not know) that the ranks of the unmarried women contain a higher percentage of eugenically desirable types, e.g. as regards intelligence, than is found in a representative sample of the general female population. (*d*) On the other hand, as women attain to greater independence—on economic and other foundations—sexual selection in mankind will perhaps become better balanced. Whenever and wherever women are able to give whole-hearted and effective preference to the best available suitor, a eugenic lever of great power is at work.

And may not what is so ancient, so manifest, and so increasing a process in humanity, and by females of males as well as vice versa, have also had its beginnings and even its not inconsiderable developments in other species in the past?

THE ISOLATION FACTOR IN EVOLUTION

Lizards of the Dalmatian Islands.—As a typical instance of the evolutionary interest of isolation we take Kammerer's careful study of the lizards of the Dalmatian Islands. In earlier times Italy and Dalmatia were united and that tract of country was in all probability inhabited by a lizard which gave rise among others to the modern species *Lacerta serpa* and *L. fiumana*. In some of the islands which now mark the submerged area there are intermediate forms which have not been markedly differentiated in either direction. A reconstruction of what probably took place indicates that *L. serpa* spread mainly to the south and west into Italy and its Adriatic islands, while *L. fiumana* extended mainly to the east and north into the Balkan region, where it gave rise to *L. taurica* and *L. ionica*. At the present day Istria and Dalmatia are inhabited by *L. serpa* and *L. fiumana*, which probably spread from the North Adriatic area. On the whole, *L. serpa* frequents the coast-lands and *L. fiumana* the interior, but there are occasional encroachments of the one species into the other's territory, though there is in such cases neither biological nor topographical mingling. There is often a lizardless neutral zone.

From this mainland distribution that of the islands has followed.

(*a*) When large islands were separated from the mainland, they would contain *L. serpa* and *L. fiumana* (as is true to-day of Ugliana and Veglia) or their common ancestor.

(*b*) When small islands were separated from the coastal fringe, whether of the mainland or of a large island, they would contain

L. serpa only. But an insulated mainland mass or the centre of a large island that had given off peripheral islets, would contain only *L. fiumana*. This sharp isolation would be facilitated by the lizardless neutral zones already referred to, and the insulation of some of these would account for islands without any lizards at all.

(*c*) If a land-complex inhabited by *L. fiumana* only gave origin to islands, the same would be true of them.

(*d*) But in some parts of the mainland (North Dalmatia to the mouth of the Narenta) *L. serpa* seems to have subsequently established itself, although previously separated off islands had contained only *L. fiumana* (*c*). And conversely (*b*), an island may contain only *L. serpa*, though the nearest tract of mainland contains only *L. fiumana*.

The details are intricate, but the first point is that the occurrence of *L. serpa* and *L. fiumana* on the Dalmatian Islands can be accounted for in terms of their geological history. The second point is that variation is going on, and that "each island has a form (a Phenotype) which is different from the forms of all the other islands and mainland-areas". When the distinctive features of the islet forms are not demonstrable in the young, they are seen in the adults; and, conversely, when the adults are on the average almost the same, the young forms are sometimes distinctive.

But when Kammerer speaks of there being a distinctive "form" on each small island, he does not mean that a specialist could from an individual specimen at once tell from what Dalmatian island it came. He means that the lizards on each island are in a phase of saltatory variability, which requires a curve of frequency for its expression. The point is that on each island there is a distinctive variety with its own range of variations at present continuing. Many of the varieties are not yet fixed; they are *in statu nascendi*; but in some cases they have passed beyond endless flux towards stabilisation. Thus there are six named and described varieties of *L. serpa*.

Kammerer finds that the observed variations are what he calls, not very happily, *bipolar*. That is to say, they seem to occur along definite lines in opposite directions, plus and minus. This agrees well with what we have spoken of in another section as the anabolic and katabolic alternatives of variation. In any particular island the variational movement is usually in one direction, but the opposite movement may be seen in a different one. It may be useful to contrast these extremes in parallel columns:

[Plus.]	[Minus.]
Total Melanism.	Lightening of Colour.
Gigantism.	Nanism.
Thick stumpy tail.	Elongated thin tail.
Very small granular scales.	Enlarged scales.
Slowness of movement.	Agility.
Tameness.	Shyness.

It does not seem far-fetched to say that these two opposite trends correspond to our predominantly anabolic and katabolic alternatives of variation and evolution. But it should be noted that these contrasted characters may to some extent vary independently of one another; thus size, shape, and activity may vary independently of colouring. We do not as yet know enough to say that a dominant metabolic ratio *must* involve the whole organism in its grip, but it cannot be a mere coincidence that the plus variations of lizards include much melanin as well as large size and thick tails (see section on Pigments). What impresses one, however, is the intricacy of the facts and the need of precaution against false simplicity; thus, to take a single instance, the variational tendency in *L. serpa pelagosæ* is towards a *lightening* of the ground-colour, yet this is associated with a *darkening* of the pattern.

The varied environment on the islands probably acts as a stimulus to variation, but that the different types are due to any simple modification, would be too simple a view, thus while the variety last mentioned tends towards lightening its ground-colour on the island of Pelagosa, a snake characteristic of the same island has varied in the direction of a dark ground-colour, "like roasted coffee-beans". Another complication is that we cannot exclude the possibility that some of the apparent trends of variation are the outcome of processes of Natural Selection at present going on, thus there is protective value in lightening of the ground-colour, which tends to inconspicuous green on the mainland and on large islands with dense vegetation.

In regard to the establishment of variations in colour and pattern, Kammerer has much to say. He distinguishes (A) temporary changes, which are commonly called individual adjustments or transient modifications, from (B) permanent changes, which are more usually interpreted as germinal or constitutional variations. But Kammerer maintains that the permanent changes pass through a phase of fluctuation before they become established.

The temporary changes (A) may be illustrated by the sometimes very pronounced darkening of the same lizard in the course of a day with a high sunshine record, or by seasonal changes in the same individual, which tends to be more brilliant in spring and early summer, more soberly coloured in midsummer and autumn.

As to fixed colour-changes, Kammerer distinguishes a number of grades. (*a*) There are progressive individual variations, e.g. when a single lizard becomes permanently very dark, *as if* there were a fixation of the modification or adjustment that follows intense sunshine. (*b*) There are manifold ("plural"!) variations which occur in the majority of the individuals, and seem to be usually occurring progressively in a definite order—first in the adult males, then in

the adult females, and then in the young forms. Kammerer reports that on some islets all the adult males had varied in a certain direction, but only half of the adult females, and none of the young ones. It is thus easy to understand that an inspection of the lizards without analysis of sex and age would give an erroneous impression of what was going on. And this masking of orderliness in variation may be increased by a fact which Eimer noticed in 1881, that the change in the dorsal ground-colour of a varying individual works from the tail-region towards the head (Eimer's "Law of postero-anterior evolution"). Another complication is the occurrence of conservative individuals or even strains which do not share or are at least laggards in the general movement (*Rückstände*), and of reversions (*Rückschläge*) which hark back to an antecedent phase, especially to that seen in the young forms. It must have required very careful study to distinguish between the "laggards" and the "throw-backs". As the variation proceeds towards completion (e.g. total melanism) the individual reversions and transilient mutations become rarer and disappear; and Kammerer believes that this holds for other characters besides colouration.

What is the precise influence of the insulation? In the first place, there are no peculiar "island forms". In the second place, while the same variants *may* occur on the mainland and on islands, the range and frequency of variation is much greater among the islands. In the third place, though at first it may seem paradoxical, the island lizards frequently show a persistence of old-fashioned (palingenetic) features along with new ones. In the fourth place, it seems practically impossible to correlate the variations established in different islands with peculiar conditions which would afford opportunity for the action of natural selection.

To take the last point first, these lizards have almost no enemies, except one another. In crowded places, which are common, the young forms are often devoured; but variation is least seen among the young. Dark pigmentation may protect against too intense illumination and light colouration sometimes makes the lizard inconspicuous against its background, but the variations are too manifold to admit of more than occasional interpretation in terms of natural selection.

Kammerer's general position is: (1) that the conditions of life on the Dalmatian islands are very diverse: as regards size, soil, surface-relief, colour of rocks, humidity, temperature, illumination, and vegetation, (2) that the environmental diversity affords numerous liberating stimuli to variability, and that environmentally induced changes may be hereditarily entailed and increased; and (3) that the insulation serves automatically to accelerate the process of fixation by narrowing the range of inter-crossing. But besides being a cradle for what is novel, an island may occasionally serve as a

shelter for a strain that is for some reason or other conservative, and not, for the time being, susceptible to variational stimulus.

Besides observations, Kammerer made numerous interesting experiments. Thus lizards subjected for a long time (up to two years) to high temperature became dark in colour, more rapidly in conditions of drought. Humidity made the colour lighter; humidity combined with lowered temperature did not accelerate the change, but carried it further. It was not possible to expose the lizards to more natural sunshine, for they already enjoyed the maximum; but conditions of shade induced some lightening of the colours. In the case of the freshwater crab (*Potamon fluviatilis*), shutting off direct illumination resulted in a change of the colour of the upper surface from the normal brown to black. On a white ground the lizards become lighter, on a black ground darker. A very important conclusion, bearing on the whole process of organic evolution, is that the progeny of modified individuals exhibit similar modifications when they are reared, not in the new conditions, but in intermediate (*mittleren*) conditions, where control-specimens are unaffected. When the offspring of the modified individuals are reared in the new conditions, they go further in the same direction, if that is possible.

The black variety of *Lacerta serpa* (*mellisellensis*) becomes slightly lighter when kept in cool humid surroundings, but the offspring kept in the same conditions become as markedly light as the original form. We must notice, however, in regard to Kammerer's conclusion, that it will be necessary to take account (*a*) of the longer time of exposure to the new conditions, and (*b*) of the influence of these on the plastic young stages. Even the reproductive organs within the parent may be affected, as in Agar's water-fleas (see section on Transmissibility of Modifications).

SUMMARY.—There are hundreds of Dalmatian islands and each has its own facies of lizards. All are descended from *Lacerta serpa* and *L. fiumana* or the common ancestor of these. The variations that are at present continuing can be grouped for the most part as alternatives in opposite directions—expressing increased and decreased activity, size, darkening, and so forth. The established or permanent strains have their analogues, if not antecedent stages, in individual modifications which are observed to occur. There is in many cases a definite sequence in the fixation of a new departure, e.g. in the adult males first. Arrests and reversions also occur. The results of experiment corroborate what is suggested by observation—the fundamental importance of environmental diversity. Whether the environmental peculiarity produces a direct modification which is entailed on the offspring and carried further in subsequent generations (as Kammerer believes), or whether it acts as a liberating stimulus on germinal variability, must remain, for us, a

disputable question. But Kammerer's work brings out very convincingly the importance of spatial isolation in fostering new strains. He has furnished incontrovertible evidence of the importance of isolation as a factor in Organic Evolution.

THE FOULA MOUSE.—Foula is a little rocky island out in the Atlantic, about 16 miles west of the nearest point of the mainland of Shetland. As everyone doesn't know that it is the Ultima Thule of Tacitus, we mention this in passing. It is about three miles long and half as broad, with high cliffs where guillemots and razorbills and other sea-fowl nest in early summer and the storms rage in winter. On the rough ground from the foot of the hills up to 1,000 feet above sea-level the famous "Hill Mice" have their home. The mountains have brought forth a mouse, a mouse that is all their own.

If one is to be accurate, one must ask whether a long-tailed little creature is a mouse or a vole; or whether a mouse is a Field Mouse (Apodemus), or a Harvest Mouse (Micromys), or a House Mouse (Mus). This is not a question of species, but of genera represented in Britain. Thus, apart from small voles (Microtus), such as the Field Vole, and big voles (Arvicola), such as the "water rat", which isn't a rat, there are three British genera of mice, namely, as we have just said, Apodemus, Micromys, and Mus. A small vole can be at once distinguished from a mouse of the same size by the broader head, the blunt muzzle, the smaller eyes, the appressed ears, and the short, hairy tail. When is a mouse not a mouse? Answer: When it is a vole. When is a rat not a rat? Answer: When it is a water-vole.

So far all is easy; the difficulties begin when we come to species, by which we mean true-breeding groups of similar individuals which are readily fertile with one another, but not readily with others, and which differ from the nearest group in characters more marked than those that distinguish the members (brothers and sisters) of one family, and important enough to deserve a name to themselves. This is a useful working definition of a species. But the species of mice, there's the rub! It is here that we need the help of the people who really care about precision and who have a head for it.

Revenons à nos moutons, that is to Foula mice. In the first place they are Field Mice in the genus Apodemus, along with the common Long-tailed Field Mouse (*Apodemus sylvaticus*), which occurs all over Britain, and is probably the commonest mammal in Europe. Another well-known species is the Hebridean Field Mouse (*A. hebridensis*), of which there are four or five geographical varieties. A third species is the St. Kilda Field Mouse (*A. hirtensis*), found on the islands of Hirta, Soay, and Dun. A fourth species is

the Fair Island Field Mouse (*A. fridariensis*), which occurs on Fair Isle, with a variety on Yell. Many would add a fifth British species, the southern Yellow-Necked Field Mouse (*A. flavicollis*). So the question is where the Foula mouse comes in, and the answer that the experts have given is that it is a sub-species of the Fair Island Field Mouse, and should be called *A. fridariensis thuleo*. How very thrilling!

But that is just what it is, for in these insular forms we have plainly to do with species in the making, with what the impatient anti-evolutionist is always demanding and never looking for. Just as the Fair Isle field mouse, the Hebridean field mouse, and the St. Kilda field mouse are derivable from the widespread common long-tailed field mouse (*Apodemus sylvaticus*), so the Foula mouse is at present—of course, a long present—diverging from the Fair Island

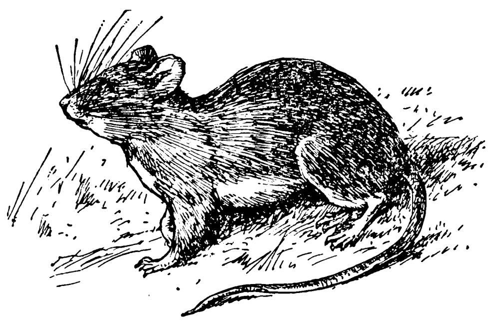


FIG. 179.

The Foula Mouse, *Apodemus fridariensis thuleo*, a variety or incipient species which has recently arisen in the island of Foula from introduced specimens of the Fair Isle mouse (*Apodemus fridariensis*), which had itself a similar origin from the mainland long-tailed Field Mouse (*Apodemus sylvaticus*).

species. Charles Darwin said in regard to the ten or so different species of giant tortoise on ten adjacent islands of the Galapagos archipelago, that he felt himself "brought near to the very act of creation", and the naturalist of to-day must say the same when he looks at the "Hill Mice" of Foula. Evolution is certainly going on, and for men as well as for mice.

It is reasonable to ask whether the Foula mice have any salient features. But the answer to this question is bound to be disappointing, for the species of field mouse differ from one another in minutiæ—the straws from which the expert knows how the evolution wind has been blowing. Species of mice do not have much in the way of salient features; they differ mainly in the details of their skull bones! Yet it may be noted that the Foula mouse has particularly large hind feet, white on their dorsal surface, and with small sole pads. It is a sturdy mouse, but distinctly smaller than its Fair Isle ancestor. The two agree exactly in colour, having dark

flanks, a dull bluish white under-surface, and a strongly be-coloured tail, dusky above and white below. It will be understood that these details are of little or no interest in themselves and yet they too are thrilling, for they are indicative of the origin of a new species.

We come here to the true inwardness of the whole matter. Why has the little island of Skomer, off the coast of Pembrokeshire, a species of vole all to itself? Why is there a St. Kilda wren, found nowhere else in the world? And why is there a Fair Isle field mouse, different from every other mouse, though approached by its recently discovered probable descendant on Foula? The answer is that isolation sometimes plays an important part in species-forming, and mainly by restricting the range of intercrossing, so that new departures or variations tend to become racially fixed.

The probability is that some vessel, perhaps a fishing smack from the south, visiting Fair Isle many years ago, had as stowaways a number, perhaps only a pair, of the common long-tailed field mice. It is possible that these differed a little from the normal stock, perhaps in being slightly more adventurous. Anyhow, the probability is that the stowaway mice landed on Fair Isle and found things comfortable. In due course they had offspring, which, as often happens, showed certain germinal or constitutional novelties. It is possible that these new departures (variations or mutations) were induced in the germ-plasm of the original settlers by some idiosyncrasy in the new environment. As generation succeeded generation, the new departures might be augmented by fresh germinal advances in the same direction (orthogenesis). But in any case, if the new departures were not fatally disadvantageous, they would tend to become more and more marked by the pairing of similar forms. For there were no dissimilars to cross with. So the Fair Isle species arose, and so the Foula species is arising.

SPECIES AND HABITAT

THE POCKET GOPHER.—We should not speak of *the* earthworm, for there are many different kinds; and the same is true of the Pocket Gopher. It is not one but many, and they spread over the whole United States west of Indiana and the lower Mississippi, and more besides. Anatomically, they are not very far removed from mice and rats, but they are broader in body, and marked by a big pocket in the skin of each cheek, which they use for carrying food home to their burrows.

The damage they do is immense, for they devour the roots and bark of fruit trees and all sorts of vegetables and cereals. They spoil the meadows by throwing up hillocks of loose earth, often as

numerous as the mole-hills in a badly infested field in Britain. They also break down the banks of canals and streams by honeycombing them with their tunnels. They are extremely costly animals. The Red Pocket Gopher of the fertile Mississippi valley, whose body is about seven inches in length, with three more to the tail, is so destructive that an authority who ought to know says: "No animal in the West is more universally disliked or more diligently destroyed." They are trapped and poisoned in thousands—in thousands on one plantation in one year; they have their natural enemies in weasels and poisonous snakes, foxes and coyotes, hawks by day and owls by night, and yet they flourish! They are not only non-social, but live on positively bad terms with one another. The old ones are usually found living alone. They have poor sight, heavy bodies, short legs, and rather clumsy movements outside of their burrows. They are, so far as we can judge, rather stupid animals. And yet they flourish!

Thus our first question is: How do these destructive rodents hold their own in spite of handicaps and enemies and man's commendable retaliations? They extend from Panama to Saskatchewan, and from sea-level to the timber-line at above 13,000 feet on some of the high mountains of Mexico. Part of the explanation is easy enough; they have an extensive vegetarian bill of fare; their chisel-edged incisor teeth are very sharp and strong; they use these teeth to help in burrowing, which is mainly effected by the strong claws of the fore-feet; the working tunnels are usually less than six inches below the surface, but there are interesting adaptive details, such as an occasional drop of two or three feet to the living-room, the setting apart of special store-chambers, and the use of short side branches as sanitary conveniences. As gophers dislike the light, they do not often show face by day, unless it be to make a short excursion to food plants near at hand. It is obviously a great advantage to be able to stuff the cheek-pockets with seeds and bulbs and pieces of plants, and to take these home to be stored. The pockets are packed by sideways movements of the front feet, used as hands so quickly that the details can hardly be followed. In the process of unloading the hands press on the distended pockets from behind forwards. In adaptation to gnawing and burrowing there is a fine development of muscles about the broad head, the fore limbs, and the anterior body. As might be expected in burrowers, the ears are reduced to small fleshy rims around the openings, which means, we take it, that germinal variations in the direction of vestigial ear-trumpets were advantageous, while individuals that persisted in having prominent pinnæ would be eliminated.

Speaking of burrowing, we may cite the fact that gophers can run backwards as well as forwards in their burrows, the rather short, well-innervated, tail serving as a guide when they move in that

direction. Mr. E. W. Nelson also notices that when the gopher is not digging, it folds the long claws of the hands against the palm and walks on the back of them. And so we might continue to demonstrate that Pocket Gophers are bundles of fitnesses, like most other well-equipped animals. They are not remarkably prolific as rodents go; thus Hornaday says that the Red Pocket Gopher has only one family in the year, and only two or three young ones in a litter.

It looks, then, as if there were some additional reason for the success of Pocket Gophers, and that has been discovered and explained by Joseph Grinnell, of the University of California. He deals in particular with the genus Thomomys, to which all the gophers of California belong—a genus that has been very successful within certain geographical limits since the Miocene period, when it seems to have evolved from a squirrel-like ancestry. The genus is represented in every county in California, "from below sea-level to almost the highest altitudes, from the hottest to the coldest portions of the State, and from the driest to the wettest belts". But the significant fact is that the genus has been broken up into no fewer than 33 different races (species and sub-species), no two of them occupying precisely the same territory. The Californian Pocket Gopher genus has been divided into sub-stocks, each of which has found its own particular niche of opportunity.

Some stocks are at home on mountains, but each stock has its own favourite altitude; others occur in valleys that have springs, and others on river deltas; distinct groups are sequestered in oases in the desert, surrounded by unoccupiable stretches which, with their feeble powers of locomotion, the gophers cannot cross; others live in humid coastal belts and others on sand dunes.

The ætiological point is that different species or sub-species have learned to live in diverse habitats—different in altitude, rainfall, temperature, light, soil, and vegetation; and each well-marked type of habitat is correlated with particular features in its gophers. Although the genus is highly specialised, e.g. for burrowing, it has retained a measure of detailed plasticity which has enabled each stock to make the best of its particular kind of haunt. Somehow or other, "each of the many and diverse 'gopher differentiation areas' found in California has impressed its occupant with its stamp, namely, a peculiar combination of adaptive characters best fitting that gopher to carry on successful existence in that restricted area."

It has been suggested that gophers are sometimes of service to man inasmuch as they bring sub-soil to the surface and bury the debris of plants. Thus they act, like gigantic earthworms, as soil-makers. Otherwise, from man's point of view, they have no redeeming quality. And yet we must recognise another service to man,

for gophers are wonderfully instructive to the evolutionist. It's an ill wind that blows nobody good!

LICHEN AFTER LICHEN.—An interesting study that finds many illustrations is the succession of different forms of life in the same place. We see this if we watch a clearing in the forest for a number of years in succession. We see it if we make a careful study of the sequence of living creatures in a hay infusion—one type following another till nothing is left but water. The successive types or associations of types do something to the environment that opens the door to successors and, directly or indirectly, involves their own exit. A good illustration has been recently disclosed by Mr. C. C. Plitt, who has made a study of lichen succession. When we climb a mountain above the region of grasses and mosses and Alpines, we reach a lichen-vegetation clinging to the bare rocks and assisting in the very beginning of soil-making. These lichens succeed in gaining a livelihood where nothing else will live because they are dual plants, as everyone knows—Algæ in close mutually beneficial partnership (or symbiosis) with Fungi. What neither plant could do alone, they can do together. They live and thrive, but they are mostly of a closely clinging encrusting type. In less exposed places the same substratum, whether rock or tree, shows a succession. The crustose species are succeeded by foliose species. Then there is a struggle for existence between these, and the more loosely growing forms with ascending margins replace those that cling very closely. Later on, there arise fruticose species like the Reindeer Moss, suggestive of miniature fruiting shrubs. The trunk of a tree sometimes shows a prolonged succession of lichens, ending in the greyish pendent Usnea having sole possession. This is one of the many aspects of the Struggle for Existence.

ACCLIMATISATION AND BIOTECHNICS

Up to this point our discussion has been essentially biological, though the human factor has none the less come in, and indeed frequently. But in these times of ever-growing population, and with rising standards of life as well, the questions of Acclimatisation must increasingly range further and further beyond our limited scientific inquiries, and become more and more of regional, national, and thus worldwide importance, Already this has become of increasing and active importance, as so notably in Canada, for which the selective production of varieties of wheat, capable of more and more rapid growth in the shortening season as we go northward, has added and still goes on adding, vast regions to the plough. In such cases, of course, we are going far

beyond acclimatisation in its naturalistic sense; yet all it can teach us may be helpful. For statesmen must more and more go on evolving from politicians to veritable geotects; and thinking of the countries under their control as no more distant provinces for indiscriminate exploitation, as still too much; but rather as regions to be developed with all the skill and knowledge that the botanical and zoological sciences, and often their utmost specialisms, can contribute to the guidance of forestry, agriculture and horticulture on the one side and to utilisable animal acclimatisation and adaptation on the other: and this from polar to equatorial regions. All this has in too many ways no doubt a tragic prospect for the nature-lover; who has been doing well, yet must still do far more, and even better, for the preservation of great nature-reserves, national parks, and minor life-sanctuaries of all kinds. Yet it is also to the like naturalistic spirit, more as yet than to the economic quest, that the introduction of new trees, new flowers, etc., to our forests and gardens has been due; and similarly often the introduction of new animals. The tax is that in many cases the introductions have included pests as well, and weeds too. Nowadays too careers are opening rapidly for trained zoologists and botanists in economic service over the world; and these are often justifying themselves so conspicuously as to be now manifestly the beginnings of a world-wide public service. Thus when an introduced species becomes a pest, it is often successfully dealt with, as by the introduction of its home enemy, parasitic or otherwise, and so on. Such economic botany and zoology has thus already its technical societies and their publications, reinforcing, and when need be criticising the work of government departments, and of agricultural and kindred associations.

Here, then, in short, is the moment for one of those general views of evolutionary biology in the past, and of its applications in the future, as man's dominance over the world of living nature extends, and this, we may surely hope, in more orderly and even beautiful ways, since biotechnic and geotechnic, than the rude and reckless exploitation, and of inorganic nature especially—so often even geoclastic and bioclastic, for which the industrial age has been and still is so largely responsible. Now that we are again beginning to see the need of making our human groupings of village, town and city again more worthy of civilisation, so surely must our regional and rural developments be made ever more worthy of the essential concept of applied biology—and with this the psychologic, social and ethical sciences and arts as well—that of *making the best of our world for man's continued evolution of humanity and all associable forms of Life.*

ACCLIMATISATION is the process by which plants and animals become racially adapted to a change of climate. This may follow introduction into a new country with a different climate, as when

sheep taken to a colder area have offspring with thicker fleece, or when plants taken to high altitudes have generations of progeny with increasingly woolly leaves, lessening the loss of water. But the term may refer to becoming adapted to a change of climate within the same country, as might occur if an Ice Age or a period of aridity set in. The difficulty, as will become evident, is to get at facts which demonstrate acclimatisation as an actual process, if the term is used in the strict sense of becoming in the course of generations adaptively changed so as to withstand climatic influences which were at first unfavourable. When a plant or animal is transported to a new country and gets on well, in itself and in its descendants, it is said to be naturalised. But there may be naturalisation without demonstrable acclimatisation. Thus some investigators, e.g. G. M. Thomson (1922), who find little evidence of acclimatisation in the strict sense, prefer to keep to the term naturalisation, which expresses an indisputable fact that organisms may thrive well when taken to another and in some aspects different country. Willis (1922) defines acclimatisation as "the accustoming of plants to new conditions and climates till they are not only capable of growing there, but also of reproducing themselves freely". Thus, though the cherry and apple will grow well in the hills of Ceylon, they are not acclimatised, for they do not produce fertile seeds *Effects of Naturalisation* (1922, p. 29).

When plants and animals get a footing in a new and different country, what changes may be looked for? (1) There is often a marked increase in the number of individuals in a given area, as is familiarly illustrated by the multiplication of the rabbits in Australia, or of greenfinches and skylarks in New Zealand. The reason is twofold: favourable conditions, such as abundant food, may increase the rate of multiplication, and there may be an absence of the enemies and other checks which kept the numbers down in the old country. There have been some costly verifications of the numerical increase that is apt to follow naturalisation, as in the familiar case of rabbits in Australia and New Zealand.

(2) If the introduced plants or animals do not multiply at all, there obviously cannot be any naturalisation, but it is possible that the reproductivity may be diminished without making naturalisation impossible. Thus the Canadian Pondweed has taken firm hold in European streams and canals, although it has ceased to multiply sexually; and as above mentioned some fruit trees may flourish well in new countries, yet never produce fertile seeds.

(3) Another consequence that has been repeatedly noted is increase in individual size and apparent vigour. The new conditions prove unusually stimulating. Speaking of plants introduced into New Zealand, G. M. Thomson writes (1922, p. 504): "Water-cress—a plant of two to four feet in length in European waters—grew in

some streams to a length of from twelve to fourteen feet, and with stems as thick as one's wrist; the common spear-thistle, which is from two to five feet high in Britain, formed in some districts vast impenetrable thickets six to seven feet in height; brambles, briars, and other weeds took possession of whole districts, and threatened to choke out all other vegetation." This riotous exuberance is due positively to the stimulating conditions as well as unembarrassed opportunities of the new territory, and negatively to the absence of the previous checks. The pruning shears of natural selection have more or less ceased to act—for the time being.

The popular interpretation of the rapid spread of introduced plants, e.g. "weeds", in new countries, is that they come from places where the struggle for existence is keener and where they have therefore become particularly efficient. According to Willis (1922, p. 7), "the real explanation, in all but a very few doubtful cases, is that their spread is due to change of conditions. This has usually been effected by man, who has often altered, or even destroyed, the conditions under which many societies of plants formerly flourished, thus giving a fair field to those new comers that were suited to the new circumstances."

(4) Many naturalists have come to the conclusion that the lessening of the stringency of natural selection after transport to a new country has allowed an increase in the number of varieties, and the survival of peculiar forms, which would have been speedily eliminated in the original environment. Thus, if there are few enemies, one might expect more numerous conspicuous variants, such as albinos. Supporting this view, Buller said of birds introduced from Europe into New Zealand: "Albino sparrows are far more common than they are in their native country; and even the skylark not infrequently changes its sober dress for a yellowish-white one." Here the careful work of G. M. Thomson (1922) is of great value. In 1891 he also found good reasons for concluding that conspicuous colour-variations were on the increase among the progeny of the rabbits introduced into New Zealand, and also among introduced birds like sparrows, thrushes, blackbirds, skylarks, and starlings. Thirty years later he definitely withdrew this conclusion, the fallacy being that he was at first so busy looking for anomalous characters that he met with many, and unconsciously exaggerated the ratio of their occurrence. In 1917 he wrote: "I cannot find now any more white, coloured, or white-feathered birds than were to be found in 1876. There are different varieties of birds in different parts, but no variations seem to be now taking place more than occurred before." Alluding more generally to the belief that the removal of checks in the new country allows variation to proceed very rapidly, he writes (1922, p. 513): "After nearly fifty years of fairly close observation I have to state very definitely that such a belief has

been absolutely dissipated. I am aware of no definite permanent change in any introduced species." But inquiry must be made in other fields to see whether there is nothing to be said for the old view.

(5) So many naturalisations have been effected in different parts of the world that one would expect to find it easy to collect instances of change of habit; but there seems to be a strong conservative tendency among animals introduced into new haunts. When domesticated animals are transported to a wilder country there is sometimes an interesting individual rehabilitation of a long lost ancestral trait. Thus cows taken from Scotland to wilder conditions in California have been known to hide their calves in the thicket when they went to graze in the open—a revival of an ancient custom among wild cattle. Sometimes, however, something novel occurs. Thus, though sheep have been established in New Zealand for only about a hundred years, they have shown in some places the novel habit of stripping off long pieces of bark from the gaya trees. On the other hand, the Australian dingo, almost certainly a somewhat primitive type of domestic dog, feral for many centuries, remains with characteristic dog-like habits, except that it does not bark. On the whole it seems that change of habit in consequence of naturalisation is infrequent and very gradual.

(6) Some types are quickly at home in a new country, but do not show any external change. Horses, rabbits, rats, sparrows, and fowls are usually somewhat indifferent to change of climate, while a tough animal like the Yak of the Tibetan mountains refuses to thrive below a certain altitude, and it is said that Newfoundland dogs will not live in India. Very blonde people usually find the Tropics difficult, yet some men thrive anywhere.

Individual adjustments may be of much importance though they do not meet the eye; as in the case of adaptation to high altitudes. When a man accustomed to life near sea-level settles in a place like Johannesburg, with an altitude of about 6,000 feet, there is likely to be, if he thrives, an increase in the hæmoglobin content of the blood. This is due at first to a reduction in the volume of the plasma and a concentration of corpuscles, but secondarily to an increased corpuscle-formation. Increased activity has been observed in the red bone marrow, which makes corpuscles. At very high altitudes there is some evidence of an increase in the affinity of hæmoglobin for oxygen. Another change is demonstrable in the reaction of the blood, to the acid side, and this is also useful since less CO_2 is required to stimulate the respiratory centre, thus increasing pulmonary ventilation. According to some authorities there is also a change in the epithelium lining the cavity of the lungs, which becomes able to force oxygen from the alveolar air into the blood. We have referred to this adaptation to high altitudes, which is in

some measure demonstrable, because it illustrates an adjustment that can only be established by intimate inquiry. It is highly probable that similar adjustments are exhibited by many animals when they have to face a marked climatic change.

Many facts confirm the suggestion that the success or failure of attempted naturalisation may depend on inconspicuous constitutional peculiarities. Thus G. M. Thomson (1922) notes for New Zealand that the greenfinch and the chaffinch have thriven remarkably, while the allied linnet has quite failed. "The reasons for these failures are often so obscure that no plausible explanation has yet been given." "The Pacific-coast salmon (*Onchorhynchus quinnat*) has become strongly established on the east coast of the South Island; while all attempts to naturalise the Atlantic Salmon (*Salmo salar*), though carried on unceasingly for half a century and in half a hundred different streams, have absolutely failed." Further biological inquiry should be made into the reasons for failure.

A hint of the frequent subtlety of conditions may be found in cases where the attempted naturalisation of a plant fails, as of heather in Ceylon, because the associated root-fungus or mycorhiza will not grow. Many orchids in Europe have had the like difficulty, until the mycorhiza the seedlings needed was supplied. According to some botanists, however, the obligatoriness of the symbiosis has been exaggerated.

(7) When an organismal change directly induced by some change in environment, nutrition, or habit, takes such a grip that it persists after the inducing conditions have ceased to operate, it is called a modification, or, less conveniently, an individually acquired character. There seem to be some climatic modifications, and the following may be mentioned. (*a*) An Englishman who works half his lifetime under a tropical sun may become so tanned that the deposit of melanin pigment in the skin does not disappear during all the years in which he enjoys his pension at home. He has changed his skin, but he cannot change it back again. Of course it must not be inferred that the blackness of the negro's skin was directly produced in this way by the tropical sun. (*b*) Nägeli brought some Alpine plants to the Botanical Garden at Munich, and there many of them became in the first year so much modified that they were hardly recognisable as the same species. Their descendants in the garden were also quite different from the Alpine originals. Thus the small hawkweeds (Hieracium) became large and thickly branching with abundant blossoms. The modifications were very striking, and in some cases many generations were observed—even for thirteen years. The persistence was probably due to the fact that the original modifications were directly re-impressed on each successive crop, for when the plants were removed from the rich garden to poor, gravelly soil, the acquired characters gradually disappeared,

and the plants exhibited once more the original Alpine characters. In all probability the environmentally induced modifications had not taken any grip of the germinal constitution. There was no convincing evidence of hereditary entailment. In this case, and various kindred ones, the soil was probably the most important factor, but it is impracticable at present to separate the strictly meteorological conditions of climatic changes from the others that may be involved.

It is important not to think of these matters too simply. Thus, as Goldschmidt points out, the normal development of particular characters, such as general growth and pigment formation, has been "harmonised" for a definite environment. But they have different temperature coefficients, and novel conditions may throw them out of harmony. Moreover, modifications resulting from climatic change must not be thought of as necessarily beneficial. Thus some Lepidoptera tend to melanism in the cold and others at high temperatures, without there being any demonstrable advantage in either case.

(8) If evidence could be obtained of the hereditary entailment of climatic modifications, this would serve as a basis for a Lamarckian theory of acclimatisation. What Lamarck laid stress on was functional modification, but for plants and for "apathetic or insensitive animals" he allowed that there might be importance in modifications directly induced by peculiarities in the environment, without there being any appreciable change of function. This is a distinction not always easy to draw, and in any case while one might call tanning a directly induced environmental modification, there are others which may be at least interpreted as the outcome of functional change in a new climate. It was to this kind of change that Darwin referred when he wrote (1868): "How much influence ought to be attributed to inherited habit or custom in the acclimatisation of animals and plants is a much more difficult question"—much more difficult than the question of acclimatisation by man's selection of new varieties. Darwin's conclusion was that "habit" did not count for much; but it is necessary to inquire afresh whether there are any facts supporting the Lamarckian interpretation.

Bordage records some observations on peach-trees (*Prunus persica*) grown from seed of European origin sown in Réunion. For ten years or so the trees shed their leaves, as in Europe. Later on, after twenty years, a considerable degree of evergreenness was exhibited. There was no bare period. A climatic modification was thus eventually brought about. When seeds of these partial evergreens were sown in the lowlands they grew into trees verdant throughout the year, but the same was true of seeds sown in certain mountainous districts with a considerable degree of frost. They also grew up into young peach-trees which were also evergreen. But European seeds sown in similar situations developed into ordinary

deciduous trees. This is a peculiar case and may be interpreted as follows: the original imports underwent a gradual constitutional change—some modification of their metabolism; this might affect the constitution of the seed during the period when it was still part and parcel of the parent's body. The change in the metabolism might result in the affected seeds developing into evergreens, though the direct environmental influence would work in the opposite direction. It is unfortunate that the observations were not carried further.

Another interesting case, reported by Zederbauer, concerns a Turkestan relative of the Shepherd's Purse (*Capsella bursa-pastoris*). It has apparently spread from the low country to the uplands, and the specimens growing at the higher altitudes were smaller than those below, with pink instead of white flowers, and tending to be xerophytic. In this there is nothing very peculiar, nor in the fact that seeds of lowland forms sown in the upland develop into small plants with pink flowers. But the striking observation was that when the upland forms were transplanted to the low country, they kept their characters, except the xerophytic leaves. But again there is need for an extension and prolongation of the experiments.

A famous case, often referred to, is that of the wild horses of the Falkland Islands, which Darwin studied on his *Beagle* voyage (1833). He says that the horses and also the cattle were introduced by the French in 1764. Whereas the cattle are large, the horses are small, and Darwin speaks of them as "having degenerated". "They have lost so much strength that they are unfit to be used in taking wild cattle with the lasso: in consequence, it is necessary to go to the great expense of importing fresh horses from the Plata. At some future period the southern hemisphere probably will have its breed of Falkland ponies, as the northern has its Shetland breed." Darwin seems to have regarded the degeneration of the Falkland Islands horse as due to the humid climate and the lack of suitable food; but it is difficult to believe that marked changes were effected between 1764 and 1833. It would be necessary to know more about the horses originally imported.

Various statements have been made in regard to changes brought about in the hair of sheep, goats, cattle, sheep-dogs, and even cats, when these animals are taken to a more rigorous climate. It is said that the hair becomes longer and thicker, which would be a useful adaptation. But there is a lack of precision in these statements, and a lamentable absence of measurements. It would be useful to know what additions were made to the coat after the climatic change; whether the offspring, exposed to the cold from birth, showed further additions; and the character of the fur in the grand-offspring. As regards modifications, no inference can be drawn from the occurrence of adaptive peculiarities, unless the history is known. This applies to a case quoted by Weismann (1904) from Milne-

Edwards. It concerns one of the Long-nosed Monkeys (*Rhinopithecus roxellanæ*), which lives in companies in the high forests of Tibet, where the snow lies for six months. It has a strong coat, though its relatives in the tropical low grounds have not. The thick fur in the snowy forest is doubtless adaptive, but this does not prove that it arose as a transmissible modification. Long-haired varieties of rabbits and guinea-pigs sometimes crop up apart from any known climatic stimulus, and certainly apart from cold.

On the whole we are forced to the conclusion that the evidence of the heritability of climatic modifications is as yet very unsatisfactory.

Natural Acclimatisation in the Past.—All the world over there are instances of nearly related species flourishing under different climatic conditions, and few evolutionists have any hesitation in regarding these as the outcome of divergent evolution. Alpine flowering plants have often their counterparts in the valleys. Shallow water marine animals are sometimes represented by related species in the Deep Sea. Hundreds of such cases may be interpreted as natural acclimatisations, and it may be recalled that while Darwin did not think much of man's achievements in acclimatising, he had no doubt as to Nature's powers in this direction. "We need not, however, doubt that under nature new races and new species would become adapted to widely different climates, by spontaneous variation, aided by habits and regulated by natural selection."

Three saving-clauses should be kept in mind. (*a*) When two nearly related species are thriving in climatically different surroundings, it should not be taken for granted, as it usually is, that all their differences are now part and parcel of the inheritance. Some of the differences may be modificational, hammered on each successive generation in the course of development. There is need for more experimental study of species. (*b*) There has been a tendency to strain the interpretation of specific characters as *adaptive* to particular conditions of life, such as those implied in climate. Many characteristics separating related species in different localities may be reasonably interpreted as climatic adaptations, but each case should be carefully judged on its merits. (*c*) When a species is extending its range in consequence perhaps of increasing numbers, the factor of isolation may come into operation, say, in the form of a river or a watershed, and variations may be separated off which have no particular relation to the new territory or climate in which the leaders of the advance find themselves. Thus new species may arise by the physical segregation of diversely varying contingents of an advancing army, till finally the climatic difference itself may become an isolating factor.

Accepting, with these saving-clauses, the idea of natural acclimatisation, we must now ask how it may have been effected. The

Lamarckian answer involves the postulate of the transmissibility of modifications, especially of functional modifications; and the evidence of this, conveniently summed up by Kammerer (1924) and by MacBride (1924), seems to us still inconclusive. The interpretation which seems to involve fewest assumptions is that suggested by Darwin. In discussing acclimatisation (1868), Darwin laid most emphasis on the natural selection of spontaneous variations. As to these variations he expressly says "there is no evidence that a change in the constitution of the offspring necessarily stands in any direct relation with the nature of the climate inhabited by the parents". In regard to selection, he lays emphasis on two points, (*a*) the organism's power of resistance to difficult conditions

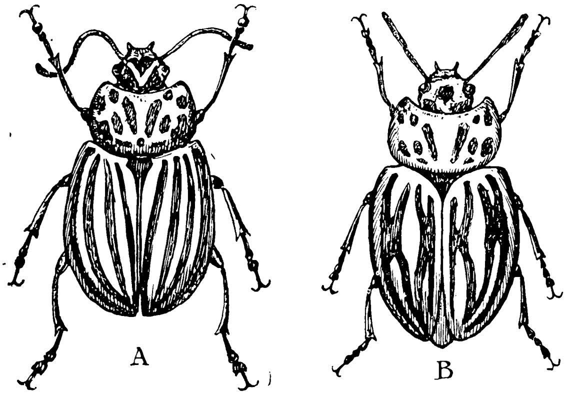


FIG. 180.
Two Variants (A and B) of the Potato Beetle (*Leptinotarsa decemlineata*). After Tower.

in the new climate, and (*b*) some useful change in the period of reproduction, such as earlier flowering and fruiting.

To Darwin's interpretation an addition may be suggested. It is conceivable that the climatic peculiarities may affect the metabolism of the organism through and through, and may thus serve as stimuli to the variability of the germ-cells. If the climatic peculiarity should induce (*a*) an adaptive modification in the body of the organism and (*b*), at the same time, a variation in the germ-cells which finds expression as a similar new character in the offspring, the phenomenon is called "parallel induction". It must be distinguished theoretically from the transmission of a somatic modification; it is, as Weismann said, a change induced in the germ-cells along with, but not through, the bodily modification.

But it is possible that climatic peculiarities may penetrate into the germ-cells and affect them without producing any modification in the body. Thus W. L. Tower subjected full-grown potato-beetles (Leptinotarsa) to peculiar conditions of temperature and humidity during the time when the eggs were maturing, and found that

"mutations" occurred in a certain proportion of the offspring. The parents were not affected, having passed the plastic stage; and some of the eggs were not affected at all. Moreover, the same environmental peculiarity, analogous to a climatic change, did not always evoke the same mutation in the offspring. Some of the mutations in colour and markings were very striking; others affected minute details of structure. There was no reversion to the parental condition. This case is of particular interest in connection with acclimatisation; for the artificial environmental conditions, effected in large steel and glass cages, were comparable to different climatic conditions in which different species of potato-beetle live.

By Muller in particular it has been shown that an exposure of the germ-cells of the fruit-fly (*Drosophila melanogaster*) to appropriate doses of X-rays, is followed by numerous non-fatal mutations, which often breed true. Now there is a variable amount of gamma radiation in natural conditions, and it is possible that the amount present may be sufficient to induce mutations comparable to those which can be induced experimentally. In any case, the experimental irradiation of the ova and sperms of Drosophila illustrates the possible action of the environment as a variational stimulus. A mutation following a climatic change might have this origin. As Weismann said many years ago (1904, p. 269): "It does not seem impossible that the climate may have a variational influence upon certain determinants of the germ-plasm, for we have already seen that the influence of cultivation may incite plants and animals to hereditary variations, and that slowly increasing disturbances in the equilibrium of the determinant system may thereby be produced, which may suddenly find marked expression as 'mutations'. But there is little probability that *adaptations*, that is, transformations corresponding to the altered climate, can arise in this way!" The meaning of this last sentence is that Weismann believed these adaptations were the outcome of the prolonged natural selection of fluctuating variations in the germ-plasm.

If the thick coat of the Tibetan Long-nosed Monkey (Rhinopithecus), which seems to be so indifferent to the snow, is a hereditary character, as it seems to be, and not an individual modification, re-imposed on each successive generation, there arises the usual objection to the Darwinian theory that there is little likelihood of such a suitable spontaneous variation arising. This difficulty, which Darwin frankly faced, will be lessened if it can be shown experimentally that such a factor as cold tends to arouse a restricted number of mutations. And, apart from this, it must be kept in mind that those mutations are, on general grounds, most likely to arise and persist which are congruent with the germinal organisation that has been already established. The impression of fortuitousness is further lessened when we keep in mind the likelihood of correlated

variations, on which Darwin laid emphasis. That the natural selection of the variations would not be fortuitous is obvious if the change of climate was drastic enough to make slightly thicker fur of survival value.

The Darwinian theory, as applied to natural acclimatisation, may be briefly resumed in more technical terms. In any species in any given environment there will be an observable percentage of variation from type in a given number of offspring produced, and these variations yield a curve of frequency or probable error. The steepness of the curve is a measure of the variability of the species. The less adaptive aberrants on all sides are pruned off by selection. If the environment is changed, selection may no longer operate on the same axis as before, but may tend to prune off variations on one side of the mean more than on another. In the course of time, the apex of the curve, representing the type form, will shift to suit the new conditions, since more of the aberrants on the favoured side will live to reproduce.

Quite a separate question is this: that the new environment may increase the variability of the species, flattening the curve of probable error. The effect of this is that selection has *more material to work with*, and therefore attains its end more rapidly, although of the variations *appearing* as many will be unfavourable as favourable. We may say that a species in which there is little variation presents a greater inertia to the shifting effect of altered climatic conditions than a variable species. In the less variable species there will be relatively fewer of the favourable variations to mate with the strict type form.

Bateson's Silliman Lectures contain a valuable criticism of the somewhat facilely accepted views (*a*) that local and climatic varieties are adaptational, (*b*) that the influences of environment have directly led either to the production of these varieties or to their selective stabilisation, and (*c*) that there is gradual transition or "mass-transformation" from one species to another in response to climatic influences. Bateson lays much emphasis on the rôle of isolation and on the intrinsic character, e.g. Mendelian dominance, of the sporadic variations that are of frequent occurrence.

Kammerer's laborious study (1926) of the species and varieties of lizards on the Dalmatian Islands lays emphasis on the importance of insulation (or isolation) as a segregating factor. Variations in colouring and marking are at first directly induced as physiological reactions, but they become structurally and hereditarily fixed; some have adaptive significance and others none. He gives interesting data in regard to the lines or rules of variation which the lizards illustrate.

Of importance in connection with acclimatisation is Erwin Baur's study of cultivated snapdragons, especially *Antirrhinum majus*.

He finds a frequent occurrence of small mutations, transmissible in their entirety in Mendelian fashion, often showing themselves in "pure lines", and sometimes suggesting an enhancement of vigour as when a mutant appears with deeper green in its leaves. According to Baur, wild species of snapdragon, like garden races, have often arisen by the summation of small mutations, the summation being to the credit of natural selection, which has sifted the mutations in reference to the changeful conditions of locality and climate.

CHANGE OF CLIMATE.—So far we have considered what may happen when organisms are naturalised, perhaps acclimatised, in a new and different environment. But similar biological problems are raised when we think of the changes that occur or have occurred in the fauna and flora of a country after some drastic alteration of the climate—towards aridity or humidity, towards markedly higher or lower temperature. This is a very important inquiry: To what extent have changes of climate functioned as factors in organic evolution? (1) In extreme cases, as when a country is covered with glaciers, there may be an almost complete elimination of life, as happened over the greater part of Britain during the Quaternary Glacial Periods. (2) In less severe conditions the gradual setting in of unfavourable climatic conditions would exert a selective influence. Thus xerophytic plants with reduced transpiration would tend to survive when arid conditions enervated; quickly flowering and fruiting plants, entrenched below ground in winter, with reserves in rhizome and bulb, would tend to survive when the snow began to cover the ground for many months of the year. In a country becoming warmer there might be survival value in summer growth; in a country becoming colder, the advantage might be with the hibernators. In scores of ways a gradual change of climate would sift the fauna and flora.

(3) Some animals, able to move about for considerable distances and not too slowly, would be prompted by the spur of climatic change to shift their quarters. As the severity of the Ice Ages spread southwards in Europe, many northern mammals came with it, thus remains of reindeer, lemming, and Arctic fox are found in deposits far to the south. As milder climates set in and the glaciers melted, the descendants of some of the Arctic types, like Reindeer and White Fox, were able to trek for the north. Some, however, remained as refugees on the mountains, like the Snow Vole (*Microtus nivalis*) of the high Alps, which seems to have been a "tundra" mammal that came far south in Europe in glacial times, but was unable to return. Some of the true bird migrations, with a seasonal ebb and flow, may owe their origin in part to distant climatic changes such as those of the Quaternary Ice Ages (see Migration).

(4) It is reasonable to suppose, though difficult to prove, that change of climate in a country induced important changes of habit. Thus Barrell and Lull have suggested that continental elevation and consequent aridity, especially in the Himalayan region, led in the Miocene or early Pliocene Ages to a dwindling of the forested area where man's ancestors were at home. The alternatives were to find other forests in warmer countries, as the present-day Anthropoid apes did, or to be eliminated, or to come to earth and begin afresh on a new line of life. The last solution may have been of critical moment in the evolution of Hominoids.

It is probable that climatic changes prompted the adoption of new modes of life at many different levels among animals, for some types became fossorial and other cursorial, some scansorial and others aërial, some took to the water and others to the caves. With the new habit and habitat would be associated new variations and the evolution of fresh fitnesses.

(5) The Lamarckian evolutionists maintain that functional modifications, induced by novel habits, were (and are) hereditarily entailed. Darwin admitted this possibility, and in connection with acclimatisation he expressly says that "habit does something". In the main, however, he relied on "spontaneous variation", by which he meant, as he expressly says, that the novelties arise without direct relation to the climate.

Climatic changes in a country may also have played an important part in punctuating the life-history. A kind of variation which has not received adequate attention may be called "phasal". It includes alterations in the tempo, or rate, or rhythm of metabolic processes, or in the duration of particular phases in the life-history. In Vertebrate animals, at least, this might be brought about by variations (also, of course, requiring to be accounted for somehow) in the secretory activity of the ductless or endocrinal glands, whose hormones serve now as accelerators and again as brakes. The life-histories of many types differ from one another in the shortening or lengthening of particular arcs on the life-curve or trajectory. Here is a kind of evolution to which climatic variations may have applied a frequent spur. Thus when the rate of development was such that the life-cycle could not be completed in the first summer, there would be a tendency to favour variations in the direction of interpolating a larval phase, as in insects, suited for an accumulation of reserves, a reduced intensity of life in cold weather, a diminished exposure of vulnerable surface, and so on. In the case of European butterflies, for instance, comparatively few are able to survive as adults; not very many pass the winter as eggs; a goodly number pass the winter as encased pupæ; but the majority, including most of the phyletically older species, endure the winter as caterpillars. Opinions may differ in regard to particular cases, but it is a legitimate

and instructive inquiry to associate temporal variations in the life-curve with seasonal and with climatic periodicities.

The Arctic tundra is marked by a long, dark winter of bitter cold and a short nightless summer of intense illumination; therefore it is reasonable to postulate a prolonged process of elimination as the climate changed—an elimination of those types which did not vary in the direction of quick-flowering and quick-fruiting, dying down in winter, dispensing with all but a little water, and accumulating stores in underground parts.

Among the features of the life-curve that may be tentatively associated with climatic changes, the following may be suggested—the length of the mammalian gestation and the time of giving birth; the periodicities of migrating birds and even peculiar cases like that of the cuckoo, where the adults leave the north long before the young ones; the tendency to shorten the juvenile period when the conditions are particularly hard on youth; the interpolation of periods of winter-sleep, rest, coma, lethargy, and even de-differentiation. Every trajectory of life should be looked at in the light of the evolution of climates.

Often in the history of the earth a change towards great cold has involved severe elimination. In humid periods there tends to be abundant succulent fodder for browsing animals and extension of shelter-giving forests. Diminution of moisture, if it does not go too far, favours the increase of grasses and of grazing animals. Aridity makes the forests shrink, and prompts the search for new haunts. Here reference may be made to the work of Lull (1917), who has expounded and illustrated the effect of environmental changes on the evolutionary stream. The times of quickening, the "expression-points" or "pulsations" of evolution, may often be correlated with climatic changes, chiefly in temperature and humidity, due sometimes to topographic, at others to general atmospheric conditions. Behind these, again, lie larger factors still, such as shrinkages of the earth's crust. See also Matthew (1915.)

INTERACTION OF ENDEMIC AND INTRODUCED FAUNAS.—(1) The newcomers may destroy the indigenous or previously naturalised forms. Thus the mongoose, introduced into Jamaica, destroyed the indigenous "cane-rats" and the alien ship-rats. Or again, the introduction and diffusion of the domestic cat in Britain must have checked the increase of mice; and so, on a larger scale, have other carnivores done service in the colonies, like weasels in New Zealand.

(2) The introduced animals may become so numerous that they make life difficult for their predecessors, though they do not actually devour them. They may, for instance, seriously reduce the food supply, but they may be prejudicial with varying degrees of direct-

ness. When the Brown Rat (*Rattus norvegicus*) found its way to Britain in the early eighteenth century, it proved itself hardier, more plastic, and more fecund than the Black Rat (*R. rattus*), with the result that in fifty years the latter was almost exterminated except in places where it was continually being re-introduced by ships. But while the direct competition was real, it cannot be forgotten that man redoubled his efforts when the second rat appeared on the scene, and that such changes as the replacement of wooden houses by brick and stone, and the introduction of sewers, favoured the stronger species.

(3) Sometimes the influence is more subtle. Thus an intrusion of rabbits into a particular area may reduce the number of hares, simply because the two species are not on friendly terms, and because the hares are repelled when plants have been contaminated by rabbits. An extension of squirrels into an area may be followed by the reduction of the number of wood-pigeons. There does not seem at first sight any intersection of the two lives; but squirrels, vegetarian as they essentially are, cannot resist killing and eating the young squabs in the nest; and this is, from the farmer's point of view, a useful check.

(4) The introduction of an animal into a new country may involve the introduction of its parasites, thus rats harbour rat-fleas, which disseminate bubonic plague; and it is also from rats that pigs, and thence men, become infected with the disease of trichinosis, which is due to a small Nematode (*Trichinella spiralis*). The re-introduction of mosquitoes into an area which had been free from them for years may be followed by a recrudescence of malaria. Many of these inter-relations are very subtle: thus the problem of getting rid of Bilharziasis in Durban is easier than it is in Japan; for in South Africa the only host of the formidable adult parasite is man, whereas in Japan it also occurs in cattle. In both countries the juvenile stages are spent in various kinds of water-snails, and their abundance or rarity in turn is correlated with the presence of water-birds which feed upon them and of water-plants on which they feed. In some cases introduced plants bring an association of animals in their train. Thus Hedley notes for New Zealand that an introduced "weed-florula" is able, with man's acquiescence or help, to oust the indigenous flora, and that a "weed-faunula" (mouse, sparrow, snail, etc.) may similarly operate against the indigenous fauna. On the other hand, the introduction of hive-bees may greatly improve the yield of fruit by securing pollination.

THE CASE OF NEW ZEALAND.—The peculiar value of New Zealand in reference to the problems of naturalisation is that the introduction of the majority of the non-indigenous larger animals is more or less definitely known. (See G. M. Thomson's masterly study,

The Naturalisation of Animals and Plants in New Zealand. Cambridge, 1922.)

Apart from two species of bats, it is doubtful if there are any indigenous mammals in New Zealand; but 48 species have been introduced, 44 purposely and four accidentally. The four include the mouse and three rats, one of which, the Maori rat (*Mus exulans*), has disappeared since European settlement began. Twenty-five of the 48 species of mammals are at present well established and feral in certain districts—wallaby, common opossum, sooty opossum, pig, horse, red deer, fallow deer, Sambur deer, wapiti, white-tailed deer, moose, cattle, sheep, goats, chamois, cat, ferret, stoat, weasel, black rat, brown rat, mouse, rabbit, hare, and hedgehog.

About 130 species of birds have been purposely introduced into New Zealand since the date of Captain Cook's landing; and 24 have become truly wild, such as mallard, pheasant, pigeon, skylark, thrush, blackbird, hedge-sparrow, rook, starling, Indian minah, house-sparrow, chaffinch, goldfinch, greenfinch, and yellowhammer.

On the other hand, since 1868 nine species of birds have become either very rare or extinct, such as native crows, huia, native thrushes, the burrowing parrot (Stringops), the native quail, and the white heron. Others, which were once abundant, have been driven back into areas where there has not been much settlement. As to the causes, Thomson writes: "It must not be supposed that it is the introduced animals alone which have produced this effect, even though rats, cats, rabbits, pigs, cattle, stoats, and weasels, as well perhaps as some kinds of introduced birds, have penetrated beyond the settled districts. It is largely the direct disturbance of their haunts and breeding places, and the interference with their food supply, which has caused this destruction and diminution of the native fauna" (1922, p. 507).

What is true for birds holds also for lower animals, from lizards to insects; but again the reasons are to be found in human intervention rather than in direct competition with newcomers. This is corroborated by the fact that there have been some notable cases of increase during the last fifty years. Thus the bell-bird has become abundant in the South Island, though scarce in the North; and the harrier has greatly increased, perhaps in relation to the abundance of young rabbits. The grey warbler, yellow-breasted tit, fantail flycatchers, and the pipit or ground lark appear to have more than held their own. The wax-eye or blight bird (*Zosterops cœrulescens*) has increased very greatly since it was first recorded in 1832, perhaps in relation to the supply of animal food about houses and stock-yards, The case of the long-tailed cuckoo (*Urodynamis taitensis*) is interesting as an illustration of the complexity of inter-relations. It seems to have become increasingly numerous during

the past thirty years, and this is attributed to the increase of small European birds, whose eggs and young it eats, and also to the food afforded in and about trout-hatcheries!

THE CASE OF SCOTLAND.—Analogous to Mr. G. M. Thomson's study of New Zealand is Dr. James Ritchie's *Influence of Man on Animal Life in Scotland* (1920). Both are books of distinction. In ancient times—long before the Ice Ages and long before man reached Scotland—the British Area was simply an outlying part of the European Continent, and must have shared its fauna. But of this original fauna there are few save fossilised British remains. There set in a succession of Ice Ages, interrupted by milder inter-glacial periods. Vast ice-sheets, sometimes 3,000 feet thick, covered the whole of Scotland and most of England except an area along what is now the south coast. Almost all the old animal tenants of Scotland were eliminated. When the ice-tide began at last to turn and the ice-sheets melted, there was a re-peopling of Britain from the Continent; for there were grassy lowlands stretching across parts of the present North Sea. The re-peopling brought back not only many mammals, but lower animals as well, and many flowering plants. All the present-day native mammals came then, besides others that have since been lost. Towards the melting of the thick ice-sheets and the uncovering of large tracts of country into which colonists crowded from the Continent, there seems to have been a marked depression of the land so that considerable parts of Britain may have presented the appearance of an archipelago. This or some subsequent movement led on to complete insulation, shutting the door to further colonisation as far as the larger land animals are concerned. Small creatures are, of course, readily introduced, like seeds, on the feet of birds.

Except for some indications, not yet fully worked out, in Inchnadamph caves in Sutherlandshire, there is no evidence of Palæolithic Man in Scotland, though he lived in Britain farther south; the first-comers to Scotland, perhaps 8,000 years ago, were Neolithic, "long-limbed, square-jawed, short, but agile-limbed hunters and fishermen", using well-fashioned stone implements and weapons. Our present question is: What higher animals greeted Neolithic Man when he arrived in Scotland? The answer is: the present Mammalian fauna, minus some that have been introduced later, such as Rabbits, Rats, and domestic mammals, and plus some that have been lost, such as Reindeer, Bear, and Wolf. As regards their origin, the original Scottish mammals, present when man established himself, might be grouped in three contingents: (*a*) those distinctively Arctic, like the Reindeer and the Lemming; (*b*) those of the forests, like the Red Deer and the Elk; and (*c*) those of the plains like the Hare and the Wild Horse. A few details in regard to

some of these types may be useful, especially as a background against which to survey subsequent introductions.

Reindeer, probably of the Woodland or Caribou variety, persisted as wild animals in the north of Scotland until the twelfth century. Beside the Reindeer may be included the Giant Fallow Deer (Irish Elk) and the true Elk, the former extinct, the latter no longer represented in Britain. The Red Deer and the Roe Deer are persistent representatives of the old fauna; the Fallow Deer is a subsequent introduction.

Appearing first in inter-glacial deposits, but lasting for many centuries along with man, on probably to the ninth or tenth, was the Wild Ox or Urus (*Bos taurus primigenius*), once widespread in Europe. Man did not domesticate it in Scotland, but it may have crossed with the Celtic Shorthorn (*B. taurus longifrons*), which he brought with him when he came. The Wild Boar (*Sus scrofa*), on the other hand, was one of the early Scottish mammals, doubtless spreading from the forests of Central Europe, and it was domesticated in Scotland as elsewhere. There is an old-fashioned race of sheep in the uninhabited island of Soay, in the North Atlantic, a race which links with the Wild Mouflon of Corsica and Sardinia, one of the ancestors of domesticated sheep; and there is an old-fashioned Turbary Sheep in the Shetlands, a race which links with the Neolithic "peat sheep" which were shepherded through a great part of Europe by Neolithic Man; but there is no reason to believe that sheep-domestication occurred in Scotland. There were wild horses in Scotland before man arrived—the Celtic Pony type (*Equus agilis*), common long ago in Western Europe; and traces of these linger in the Hebridean pony and the Shetland pony. It is said that a herd lasted till 1507 in the Forest of Birse, in Aberdeenshire, but the main stock of domesticated horses probably came in the train of the Neolithic herdsmen from the Continent, notably perhaps from Scandinavia.

As to the larger Carnivores, the Wolf lingered in Scotland till the seventeenth century, even to 1743 according to some. Its disappearance was especially connected with the shrinkage and the burning of the forests, and with more determined wolf-hunting, which was compulsory as late as the fifteenth century. The Brown Bear lingered in Scotland into the Christian era, and along with it the Lynx.

Of the original small carnivores there is a persistence of Fox, Badger, Otter, Polecat, Stoat, Weasel, Wild Cat, and Marten. The last is dwindling to a vanishing point; the Wild Cat is rare, but of recent years notably on the increase. Seals continue to hold their own; but the Walrus, which used often to visit Scottish coasts, has been persecuted into extreme rarity. Most of the Cetaceans, except Porpoises, become scarcer every year.

Among Rodents, the Beaver and the Lemming have disappeared; the Common Hare and the Mountain Hare have increased, partly through preservation and partly because of the more abundant food afforded by the spread of agriculture. The Rabbit is a good instance of naturalisation, for it was unknown in Britain before the Norman Conquest. It was already common in Scotland by the thirteenth century, but it cannot be called indigenous. Both the Black Rat and the Brown Rat are aliens, the former dating from the time of the Crusaders and the second from about the middle of the eighteenth century. The small native Rodents, the Voles and Mice, hold their own, and so do the Insectivores—the Hedgehog, the Mole, and the Shrews.

Taking a general survey, we see that there has been in Scotland an introduction of domesticated sheep, cattle, horses, Fallow Deer, dog, cat, poultry, Pheasants, and a few more. The wild Rabbits were probably introduced deliberately, the Rats unwittingly. Since man settled in Scotland the fauna has lost about fourteen species of mammals and birds, and while Ritchie points out in his careful way that the total number of species is actually greater, the standard is lower. The noble has been exchanged for the ignoble—the Elk for the earthworm; the visible has been exchanged for the invisible—the beaver for the bug! "In spite of statistics and of multitudes of species, we have in effect lost more than we have gained; for how can the increase of Rabbits and Sparrows and Earthworms and Caterpillars, and the addition of millions of Rats and Cockroaches and Crickets and Bugs ever take the place of fine creatures round the memory of which the glamour of Scotland's past still plays—the Reindeer and the Elk, the Wolf, the Brown Bear, the Lynx, and the Beaver, the Bustard, the Crane, the bumbling Bittern, and many another lost or disappearing."

The case of Scotland is instructive, since the area is small and the fauna well known, and Dr. Ritchie's careful study shows the complexity of the factors that are often involved in faunistic change. Besides the alterations in climate, there are those involved in deforestation, drainage, the extension of arable land, and the reduction of wild corners. Much has depended on man's often vacillating attitude to the wild life of the country, for he sometimes preserves and sometimes exterminates. The introduction of new types has no doubt its influence on those in possession, but this is often far from being a case of sheer competition.

Where man plays a large part, two main processes may be recognised. On the one hand, there is a diminution in the number of larger and more highly evolved types, partly because they are apt to be dangerous to human life or destructive of stock and crops, partly because of fashion and a pride in "trophies", but partly as the result of slow processes, such as deforestation and the spread

of agriculture. On the other hand, "while man lops off giants at the head of the scale, he adds insignificant pigmies at the bottom", partly by carelessness, as in the case of rats and cockroaches, partly by thoughtlessness, as in the case of rabbits in Australia or sparrows in the States.

METHOD OF NATURALISATION.—What should man do when he wishes to naturalise a valuable plant or animal in a new and markedly different country? If trial has shown that naturalisation is not easy, the transporter should work with those varieties which seem most likely to be suitable. Attention should also be paid to the quality of variability, for some stocks are much more fixed than others. It may be useful to transport individuals of the most promising stocks to some intermediate station, where selection may be made among the variations that continue to arise. Darwin noted that "Merino sheep bred at the Cape of Good Hope have been found far better adapted for India than those imported from England". (*Variation*, 1868, p. 305.) In cases where success in the new country seems to depend on the possession of a particular character, such as thick fur or woolly leaves, the variants selected would be those tending most markedly in that direction, but Mendelian methods might come to the breeder's aid and enable him to "graft" on to the tentative imports the desirable character in question if it existed elsewhere in an allied race. By more systematic selection of heritable variations and by Mendelian hybridising, it seems likely that the process of acclimatisation might be greatly extended and hastened.

Willis notes (1922, p. 28) that man has often failed in naturalisation by attempting too much abruptly. Learning from failure, he is now trying gradual transitions, "as in the way he has treated Liberian coffee in Java, taking the seed of successive generations a few score yards higher up each time, till he has persuaded the tree to do well at a much higher elevation than that to which it is naturally suited."

The attempts to acclimatise the beautiful *Cyperus papyrus* in the Ceylon Botanic Garden failed when seed from Europe was used, but seed from Saharanpur in India succeeded at once. The moral is that man must moderate his impatience and take a hint at least from Nature's operations—by small steps throughout long periods.

ADAPTATIONS

Since organisms do in most cases succeed in persisting generation after generation, for longer or shorter cycles of years, they are obviously fitted or adapted to the normal conditions of their life. In other words, an organism is an integrate of many adaptations—"a bundle of fitnesses", it has been called. But the term adaptation

is often used in a less general way for *a particular adjustment of structure or function that meets a special need*. Thus the chamæleon has a rapidly protrusible club-shaped viscid tongue, as long as the body in front of the tail, well suited for the capture of insects. It has a prehensile tail, movable in an unusual way—dorso-ventrally, and thus well-suited for gripping the branches. Its hand is split into two groups of digits, three to the inside and two to the outside, again well-suited for taking a firm hold of a branch. The foot is similarly split, but it illustrates an interesting reciprocity of adjustment in having two toes to the inside and three to the outside. The pigment-cells or chromatophores in the skin are quick to expand

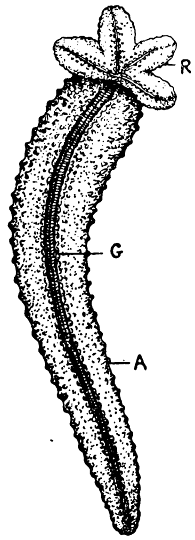


FIG. 181.

Regeneration in a Starfish. A separated arm (A), showing the ambulacral groove (G) is regrowing the four missing arms (R). This is popularly called a "comet" form of starfish.

or contract, thus altering the chamæleon's colour, sometimes at least protectively—another adaptation. These are instances of the many particular adaptations with which the chamæleon's body is equipped, and in which it differs from other lizards, which have other adaptations of their own. So it is convenient to distinguish such special adaptations from more general physiological characters, such as cold-bloodedness, or from structural peculiarities, such as the laterally-compressed skull, to which no particular adaptive significance can be assigned. From unicellular organisms onwards there is a *general adaptiveness*, so fundamentally characteristic; and we see also the resulting *general adaptations* common to large groups of organisms, which are distinguishable from *special adaptations*, such as are illustrated by the chamæleon's tongue, tail, etc.

Yet it is difficult to draw the line with firmness. Growth is a general characteristic of living creatures, and it shows primary adaptiveness in a way that is not true of the growth of a crystal. For, as we have seen, organic growth is characteristically a regulated process; over-growth, for instance, is unusual. Yet when we pass from growth in general to the particular kind of growth illustrated in the regeneration of lost parts, such as the arm of a starfish or the tail of a lizard, we are face to face with a special adaptation. Still more emphatic is this impression when we find that in many lizards which readily surrender their tail in the spasms of capture, and thus may escape with their life, there is a pre-formed breakage-plane, which extends as a soft gristly disc right through the centrum of a vertebra, or of several vertebræ, near the anterior end of the tail. And our impression of special adaptiveness is further strengthened when we notice that the capacity for surrendering and regrowing the tail, general among lizards, is not exhibited by the chamæleon, which keeps its tail twisted round a branch and out of harm's way, nor by various other lizards, like the South African Zonurus, which habitually use their tails as weapons.

In the same way there is general adaptiveness in the capacity the leucocytes of vertebrate blood have of manufacturing anti-bodies. These counteract the disintegrative action of strange proteins that may find their way in, either by wounds or by intruding enemies. But when the blood of a particular animal is rapidly and very effectively resistant to a definite poison, as the hedgehog's to the adder's venom, must we not speak of a special adaptation here?

The word adaptation is often used not for the result as we are using it here, but for the evolutionary process by which the result is reached. Thus the gizzard of a fowl, the flukes of a whale, the sting of a wasp, and the tentacles of a sundew may all be spoken of as the outcome of long processes of adaptation—more direct according to the Lamarckians, more indirect according to the Darwinians.

It has been suggested, usefully we think, that the term *adjustment* should be kept for processes or results that occur during the individual lifetime. Thus a callosity developing on a much-worn part of the skin may be a protective adjustment; and extreme Lamarckians believe that even such individual adjustments might form the raw materials of racial adaptations. The more general term "modification" is applied to any result that comes about in the individual lifetime as the direct result of some peculiarity in environment, nutrition, use and disuse, and persists after the inducing conditions have ceased to operate. But modifications are not always adjustments; they may be disadvantageous or indifferent.

ADAPTATIONS CLASSIFIED.—To start with, it is convenient to distinguish functional and structural adaptations. Of the former we may give the following instances. Warm-bloodedness, a preroga-

tive of birds and mammals, is the capacity for keeping the temperature of the blood and body approximately constant, day and night, year in and year out. It is discussed in the physiological chapter; so it is enough to say that warm-blooded animals are at a great advantage over the lower forms which are all cold-blooded, i.e. approximating in their body-temperature to that of the surrounding medium. Warm-bloodedness facilitates the metabolism of the body; it tends to maintain uniformity of its rate, and economises heat-energy. Some mammals are imperfectly warm-blooded; and most of these have saved the winter situation by becoming hibernators (*q.v.*). In newborn mammals and newly hatched birds the heat-regulating arrangements are not yet fully developed, and everyone knows that a short exposure to cold is fatal in these cases. No doubt

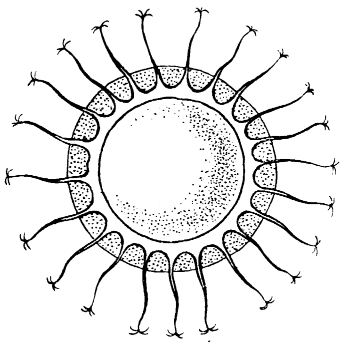


FIG. 182.

The Statoblast or "Winter-Egg" of a Freshwater Polyzoon (Cristatella). It is surrounded by a firm envelope, from which arise numerous hooked spines, adapted to effect attachment.

the keeping of an approximately constant temperature depends on structural arrangements—involving the heat-regulating centre in the brain, the innervation of muscles, of sweat-glands, and the course of the blood-stream; but thermotaxis none the less remains essentially a physiological adaptation, though requiring anatomical differentiations to function in its service.

Another functional adaptation is rapid colour change (see Struggle for Existence), which in many cases, though not in all, results in the animal becoming inconspicuous against its natural background. This rapid change of colour depends on alterations in the position and state of contraction of the pigment-cells, and these alterations are brought about in various ways: (*a*) by the direct influence of light on the skin, as in the Æsop Prawn; (*b*) by the influence of surrounding colours on the eye and a diffusing influence through the nervous system, as in flat-fishes; or (*c*) through the diffusion of hormones (from the pituitary body) in the blood, which affect

the chromatophores directly, as in the frog. But more than one kind of influence may operate in the same animal. (See Hogben, 1924.)

The regulating of functions by means of hormones (*q.v.*), the quality of immunity (*q.v.*) to poisons of frequently recurrent menace, the production of poison as a protection or as an aid in attack, the sensitiveness of phagocytes to intruding microbes, the susceptibilities of unicellular organisms to nutritive substances at a distance, the power of the alimentary tract to change foreign proteins into harmless ones, the attraction of the spermatozoon to the ovum and its movements against currents in the oviduct, or in circular orbits around an insect's hard egg-shells which have only one minute

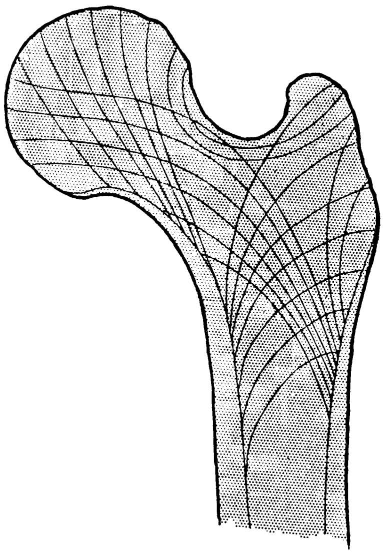


FIG. 183.

The Head of a Thigh-bone, split to show the internal architecture, adapted to withstand strains and stresses in different directions. (After Hesse).

entrance (the micropyle), or but a few—these are among the hundreds of physiological adaptations.

Passing to structural or anatomical adaptations, we admit that the adaptiveness may not be evident until the organ in question enters into activity, so that the demarcation between structural and functional fitnesses is necessarily in many cases vague. The neatly fashioned valves of the heart, which keep the blood flowing in the right direction, are of course adaptive in *functioning*, but their structural details place them in a different group from the bioluminescence by which the female glow-worm attracts the attention of a male. The luminescence is more of a *functional* adaptation; the valves are more of a *structural* adaptation, though the proof of their adaptiveness is in their functioning.

STATIC AND KINETIC.—Among structural adaptations a first distinction may be drawn between the static or passive and the kinetic or active. The internal structure of a long bone—take the thigh-bone—is arranged in a manner that arouses the admiration of the constructive engineer: its struts and stays of bone are disposed so that they meet the most frequent strains to which the leg is exposed. This is a static or passive adaptation.

The massive encasement of a tortoise (carapace and plastron)

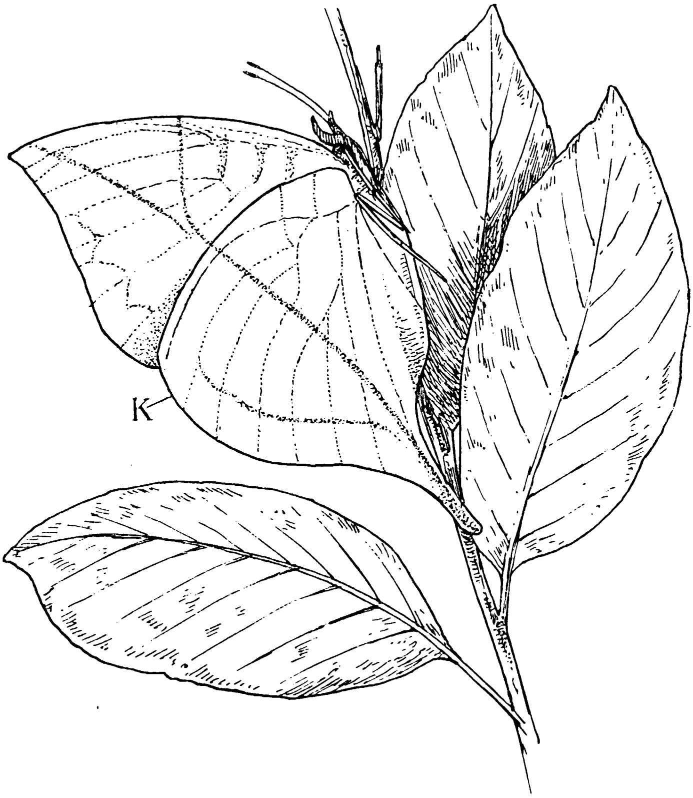


FIG. 184.

Protective Resemblance in Kallima Butterfly. From a specimen. K, the butterfly seated among the leaves, which it so closely resembles in its shape and markings.

built on the principle of an arch strengthened by the addition of a transverse base, has an extraordinarily intricate mingling of (*a*) true endoskeleton (e.g. vertebræ and ribs), (*b*) sub-cutaneous skeleton (the bulk of the plastron), (*c*) cutaneous skeleton (the vertebral and costal scutes), and (*d*) the ectodermic skeleton of horny scales. We mention this fourfold detail because it illustrates the manifoldness of what is, after all, just a rigid box enclosing the animal body. The tortoise is almost invulnerable; and it can retract head, tail, and limbs within the shelter. A very effective adaptation, yet wholly passive; a fortress, in fact.

So the shells of whelk and cockle, the exoskeleton of crab and lobster, the test of the sea-urchin, and scores of other external encasements are protective static adaptations. Yet how rare it is to find anything quite static in the world of organisms, for the shell of the cockle, like the tortoise's box, is in part of importance in serving for the insertion of the muscles of their respective locomotion. Part of the adaptiveness of the sea-urchin's rigid globe lies in its capacity for *growth*. New plates are formed around the apical disc, and each of the hundreds of plates is increased in size by contributions from hardly detectable connective-tissue cells between them.

There may be static adaptations that have nothing to do with hard parts, as we see in fixed colouration when that harmonises with

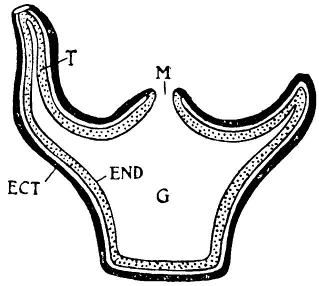


FIG. 185.

A Typical Hydrozoon Polyp, in vertical median section. M, the mouth; T, a hollow tentacle, one of the many around the mouth; G, the cœlenteron or gastral cavity, the food-canal in short, which is in Cœlentera the only cavity in the body. The symmetry is radial. The body-wall is two-layered (diploblastic), with an external ectoderm (ECT) and an internal endoderm (END). Between these there may be a structureless lamina as in the common Hydra, representing the mesoglœa of sea-anemones and other higher (Actinozoon) polyps.

the habitual background. There is surely some adaptiveness in the sandy colour of desert animals, in the green colour of some arboreal animals, and in the white colour of various polar animals; but we have already noticed that the colouration adaptiveness need not be restricted to making the animal inconspicuous.

A second group of structural adaptations includes shapes; and in these again the emphasis is partly on the passive side. Compactness of body, as in the sea-urchin, is adapted to creeping about among the rocks, for the spherical shape lessens the grip that tidal currents take of the body, and it also allows the locomotor tube-feet to be disposed uniformly in all directions. In the burrowing heart-urchins there is an interesting departure from the spherical and radial towards the cordate and bilateral, thus of evident advantage in such a difficult kind of locomotion.

The passage from water to dry land, effected by so many types, is

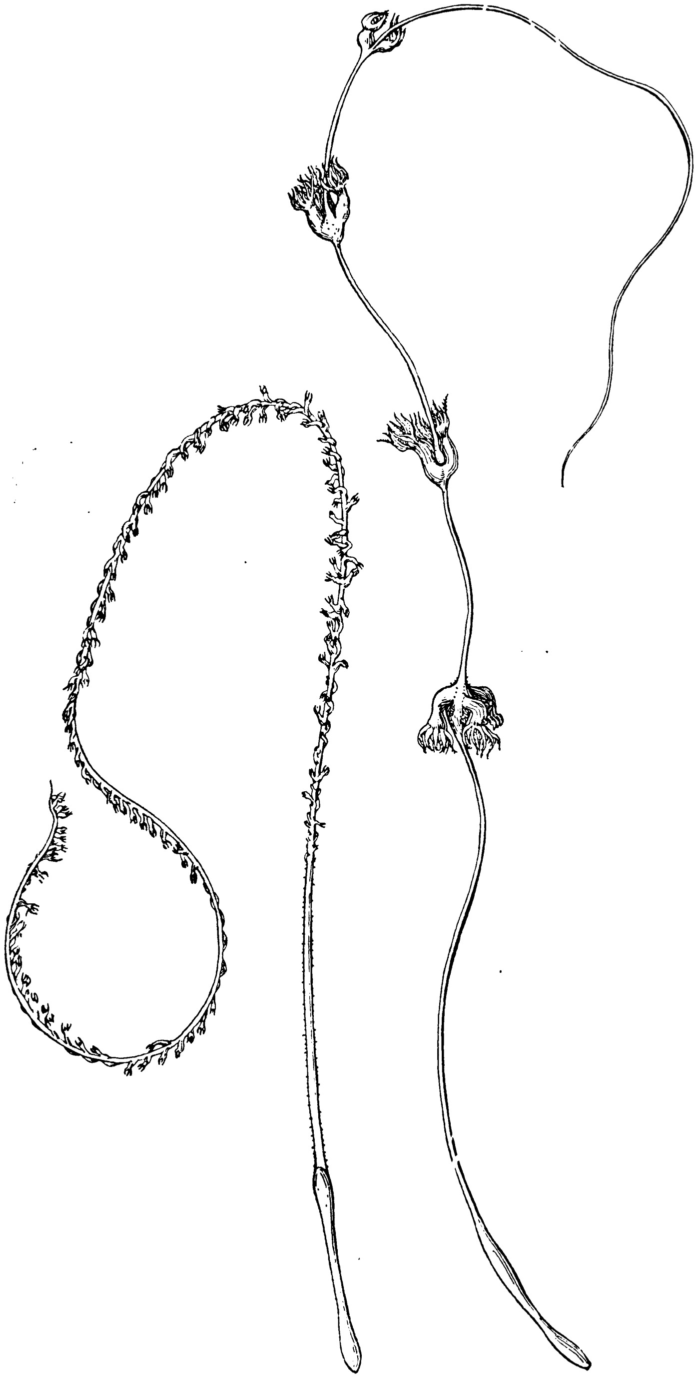


FIG. 186.

Two Deep-water Pennatulids, showing the long stalks, with bases embedded in the ooze, which lift the polyps up into the water. The colony to the right, Chunella, has the polyps in distant whorls; the other, a commoner type, Funiculina, has the polyps crowded together on the upper part of the axis, which may be over a yard in length. Both forms illustrate a simple adaptation to life on the floor of the sea at considerable depths.

associated with the assumption of more compact shapes in the case of locomotor animals. The spreading bulk of a jellyfish, with a disc over a yard in diameter and tentacles sometimes thirty feet long, could not live except in the open sea. A thirty-foot python or the like might be thought of as contradictory, but although the body is long it is compact, and by the adaptive utilisation of over two hundred pairs of ribs as oars, the nullipede has become a multipede!

EXTERNAL AND INTERNAL SURFACE

A survey of animal forms shows that two opposite tendencies in organic evolution are towards increase and towards reduction of external surface. In a sedentary arborescent organism, whether Hydroid, Alcyonarian, or Antipatharian colony, a seamat (Flustra), a coralline branching Polyzoon (like Cellepora), there is an enormous surface, and the value of this, familiar in arborescent plants, is that it spreads out the nutritive area. That nutrition, apart from the absorption of soil-water by the roots, is effected by the leaf expansion in plants, and by the tentacles and mouths of thousands of polyps in the animal colonies we have mentioned, makes little difference. An Antipatharian or Black Coral colony is sometimes like a small furze bush, and must have a very large tentacled surface, yet without crowding of the individual polyps. It may be contrasted with many of the reef-building or Madrepore corals, where the origin of new individuals, formed by budding or by fission, leads to so much crowding that the younger individuals smother their predecessors. But an arborescent animal colony is like a country with a very long coast-line indented with many fiords, so with available space accordingly.

While the increase of external surface is most marked in fixed animals, it occurs also in some that float or swim in the water. Thus a large jellyfish, with its many tentacles and its long frilled lips, bears a countless multitude of stinging-cells, whose lassos paralyse and grapple the small animals that serve as food. Interesting in this connection are the Rhizostome jellyfishes, where the usual central mouth disappears and its place is taken by a large number, often several hundreds, of minute openings which lie along the margins of the puckered and growing lips, and communicate more indirectly with the otherwise mouthless food-canal. In many of the free-swimming Siphonophore colonies of the open sea, including the Portuguese Man-of-War and its allies, there is again a very large surface; but the division of labour is pronounced, and only a certain number of the individuals are concerned with nutrition.

The adaptiveness of a large external surface in certain conditions of life is emphasised when we consider instances of its marked

reduction. Thus in many of the Cactuses and Euphorbias that live in arid regions, where the rains come at rare intervals and water has to be stored within the plant, there is a practical suppression of leaves, which are represented by spines, and the green stem takes on the ordinary functions of the leaf (absorption of air and light, and transpiration of water-vapour), but, despite its enlargement, with *a greatly reduced surface*, and reduced functioning accordingly. Thus there are quaint shapes—spherical, oval, cylindrical, and so forth—with a minimum or approximation towards a minimum of surface in proportion to volume. Thus undue loss of water in the desert is evaded.

There are other advantages in surface increase besides those associated with nutrition. Thus one of the striking features of many

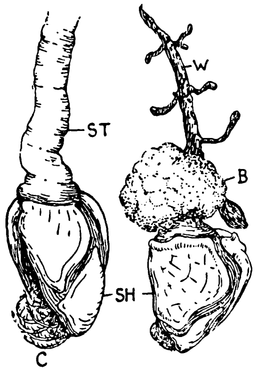


FIG. 187.

Adaptation Illustrated by the Floating Barnacle (*Lepas fascicularis*). From a specimen. ST, stalk; SH, shell; C, cirri or thoracic limbs. The floating barnacle, to the right, attaches itself to seaweed (W) and the like, which it tends to drag down as it increases in weight. But this is obviated by a secreted buoy (B). In the ordinary ship-barnacle (*Lepas anatina*) shown to the left, attachment is effected to floating timber and the like, which cannot be submerged by the relatively trivial weight. The shell of the Floating Barnacle is very lightly built.

of the smaller pelagic organisms—both plants and animals—is a notable increase of surface. This facilitates flotation, and makes the creatures almost unsinkable. We refer, for instance, to the long outgrowths, sometimes feathery, that extend from the chitinous cuticle of minute Crustaceans, like out-riggers or catamaran spars. It is interesting to compare the squat heavy-bodied Angler-fish (*Lophius piscatorius*), not infrequently cast up on the shore, with the free-swimming pelagic larva which bears extraordinary—one might say exuberant—frills and tassels of delicate skin. It is highly probable that these greatly increase the flotation-power of the larvæ; and they gradually disappear as the animal changes its habitat, and begins to feed on the floor of shallow seas. (Fig. 124).

When pioneer animals made the several times repeated transition from the sea to dry land, whether via freshwater routes or directly,

a noteworthy change had to come about—the proportionate reduction of the external surface. The possibility of cutaneous, or, in any case, external respiration, so characteristic of aquatic animals, was greatly reduced; the skin was thickened, and in many cases protected from drought and glare and attack, by cuticle and shell, by scale and scute. It was profitable to have the surface reduced; and we have already referred to the need for compact bodies in typical terrestrial animals.

Yet this led to the great development of well-packed bodies and of *internal* surfaces. Thus, taking the respiratory function, we see the need for new structures like insect tracheæ, arachnid lung-books, or plaited pulmonary sacs. Oxygen was more abundant than it had been in the sea, but it was less available, for the external surface was hardened, protected, and tending to be dry; hence the evolution of increased internal respiratory surfaces. Variations in this direction would tend to succeed; all the more since the reduction of the external surface would tend to impose, as a condition of increase, the formation of internal branches, plaits, and pouches—all making for efficiency. And what is clear in regard to respiratory organs holds also for other systems, such as food-canal, blood-vessels, and kidneys.

We are not forgetting that some aquatic animals also show great increase of internal surface. Thus there is the extensive superficial area of the canal-system in the more complex sponges, of the gastro-vascular system in jellyfishes, of the alimentary system in a Sea-Mouse (Aphrodite), of the excretory system in a Turbellarian, and so on. Our point is simply that the transition from water dry land gave a fresh impetus to the evolution of internal surfaces. It is highly improbable that the convolutions of the clever mammal's brain, implying a great increase of neural surface without corresponding increase in the size of the enclosing brain-box or skull, could ever have come about if animals had not made the great step of leaving the water for the dry land.

ADAPTATIONS IN SYMMETRY

Radial symmetry is familiarly illustrated (Fig. 185) by jellyfishes, sea-anemones, corals, and the like, by the simple vase-like sponges, and by the sea-urchins and starfishes, which Cuvier gathered together as his Radiata. We have discussed it under Morphology, so that we need only say here that it implies the possibility of dividing the animal's body into several mirroring halves by cuts in as many different planes. In other words, there is practically no right side or left side in a polyp any more than there is in a glass tumbler. It must be noted, however, that when details

are considered, this superficial radial symmetry does not usually hold quite good for the internal structure of the body. Thus there are only two cuts that will divide a sea-anemone into two precisely similar halves, namely, (*a*) the vertical cut through the plane of the two ciliated gullet-grooves (siphonoglyphs), and (*b*) the vertical cut through a plane at right angles to the first. Similarly, though a sea-urchin is radially symmetrical—not only superficially, but in the 5-rayed disposition of the nervous, water-vascular, blood-vascular, and reproductive systems—there is only one plane which will divide it into precisely mirroring halves, namely, the plane that bisects the madreporic plate and anus vertically. No other cut would give half of the madreporic plate to each of the halves of the sea-urchin.

To come to the point, however, radial symmetry is adapted (*a*) to sedentary life, as when the sea-anemone waits for food to drop into the circle of its outspread tentacles, and (*b*) to easy-going (Plankton) life in the open waters, where it matters little in what direction the animal moves, as is well illustrated by jellyfish.

Bilateral symmetry, which occurs in the majority of animals from worm to man, shows a right and left side; and the body can be halved in a longitudinal median dorso-ventral plane and in no other. This kind of symmetry, where one end of the body takes the lead in locomotion, is adapted for more energetic life than radial symmetry allows. It is suited for pursuing booty and mates, and for avoiding enemies. It is to be correlated with the evolution of head brains, that is to say variations in the direction of having neurons at the head end especially. In the testing of variations that always goes on in everyday life, those variants that had most concentration of neurons at the anterior end would have an indubitable advantage. This again should be correlated with the "metabolic gradient" (*q.v.*), which is so clearly seen in the simplest Planarian worms where the area of intensest metabolism is at the head end. It is not too much to say that if Planarian worms, or some similar pioneers, had not begun to move with their head end foremost, Man would never have been able to tell his right hand from his left.

It is interesting to notice that some animals which are sedentary or sluggish in adult life, but active as larvæ, become radial as adults, although they were bilateral in the larval phase. Thus the free-swimming Open-Sea larvæ of the shore sea-urchins and brittle-stars are bilateral. Bilaterality is adaptive to vigorous locomotion. Whether there is any adaptiveness in acquiring asymmetry, such as snails illustrate, we do not know; but it is worth noticing the case of bony flat-fishes, like plaice and sole, which are symmetrical as larvæ, but markedly asymmetrical as adults, having both eyes, for instance, on the up-turned pigmented surface. The young larvæ are shaped like those of "round" fishes such as haddock and herring,

and they swim in the ordinary position near the surface. As they grow larger, one side becomes heavier than the other, and the young fishes swim obliquely at some distance below the surface. Gradually they sink to the floor of the sea, resting and swimming, usually on their left side (plaice, sole, lemon sole, dab, etc.), sometimes on their right side (brill, megrim, turbot), whichever is the heavier. The down-turned eye travels to the upturned side and lies beside its

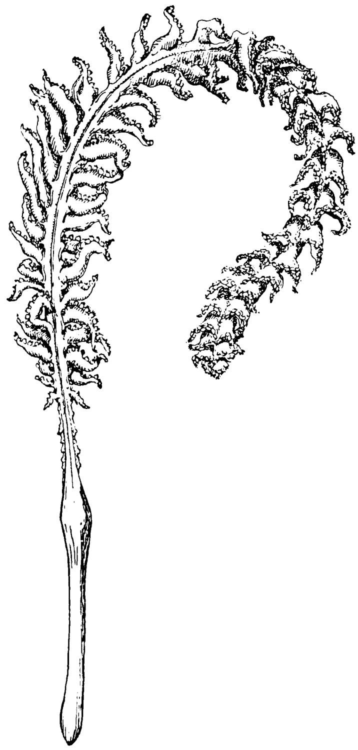


FIG. 188.

One of the Sea-Pens or Pennatulas, a typical deep-water animal. From a specimen. The stalk is embedded in the substratum. The pinnæ bear numerous nutritive and reproductive polyps or autozooids, and besides these there are numerous siphonozooids, which are neither nutritive nor reproductive, but serve to keep up currents of water in the colony.

neighbour; pigment disappears from the unillumined down-turned side, which shows only silveriness,—due to spangles of the waste-product guanin. The asymmetry is adaptive to life on the floor of the sea.

STREAM-LINES.—A structural adaptation in which the functioning of the individual has a formative share is a shape suited to a particular kind of locomotion. Thus the torpedo-like form of body in most fishes is adapted to rapid swimming, and similar stream-lines are seen in whales and dolphins, in Sirenians and seals. The serpent-like

form of body, adapted to moving through holes or in contact with adjacent bodies on all sides, is illustrated by worms, leeches, lampreys, eels, burrowing blind-worms (Cæcilians), slow-worms (limbless Lizards), subterranean snakes, and so on, and even so far by elongated sinuous mammals, such as stoats and weasels.

ADDITIONAL INSTANCES OF ADAPTATIONS

It is not easy to find a more striking instance of adaptation than that of the African egg-eating snake (*Dasypeltis scabra*), a weak-bodied creature less than a yard in length, which is able to swallow birds' eggs three times the diameter of the thickest part of its body. The jaws—of course loose-hung, as in all serpents, to aid their wholesale swallowing—have a poor equipment of teeth—few and weak. There is the usual serpent way of gripping and loosening, first on one side of the mouth and then on the other; the egg slips intact from the muscular pharynx into the elastic gullet. There it is met by the sharp, tooth-like, and even enamel-tipped(!) spines of a number of anterior vertebræ, which project into the gullet and cut the egg-shells neatly. The result of the structural adaptation is that not a drop of the precious fluid contents of the egg is wasted, and there is a final touch of perfection in the return of the empty shells out of the mouth. What an advance there is in this effective arrangement, as compared with the rough-and-ready way in which other egg-eating snakes break the shell, by pressing their throat against the ground.

Adaptations of Soft Structures.—One has only to think of organs like the eye or the heart to realise how many distinct adaptations may have to be integrated towards the perfecting of a single function. Let us take a simple and familiar case—the gizzard of a grain-eating bird, such as the fowl. Its function is grinding the hard food, and it is adaptive (1) in its great wheel-like muscles, whose contractions bring the walls near one another; (2) in its horny lining, which protects the internal surface from being injured by the pebbles which have been swallowed to serve as grinding-stones; and (3) in its curvature, which lessens the risk of the food passing into the intestine before it has been ground. This gizzard is a transformed portion of the stomach, but is now non-glandular; and the problem of its evolution presents no particular difficulty, especially since we know that the stomach of a particular species of bird may show considerable plasticity according to the diet for the time being. Thus the stomach of the herring-gull has a predominantly soft wall in winter, when it is feeding on fish, and a much harder wall in summer, when it is stealing not a little grain from the harvest-fields. This individual plasticity is interesting; yet it is quite possible that it

throws no direct light on the evolution of the gizzard in birds that live on hard food.

A very effective "stomach" is found in the cud-chewing ruminants, where the lower end of the gullet or œsophagus has been specialised to form the rumen or paunch, the reticulum or honeycomb, and the psalterium or manyplies, the true stomach, with its gastric glands, being represented by the fourth chamber, the abomasum or reed.

The right ventricle of the heart of the ptarmigan, which lives at high altitudes, is distinctly stronger than that of its near relative the willow-grouse, which does not ascend so high. This is an easy adaptation to account for, since individual inborn variations in the muscularity of the heart are well known and frequent. The fish called Anableps that lives in the estuaries of Brazil and Guiana has the habit of swimming at the surface with its eyes half out of water; the upper half of the eye is adapted for vision in air; the lower for vision in water; the curvature of the two parts being different. This is a difficult adaptation to account for. Mr. J. T. Cunningham writes: "It seems to me that we have no reason to suppose that the required variations ever occurred until the ancestors of Anableps took to swimming with their eyes half out of water." His Lamarckian interpretation is that the peculiar habit directly brought about modifications in the eye which became by hereditary summation a racial character. This is a good case, and Mr. Cunningham has an expert knowledge of fishes; but on the other side it may be pointed out (1) that there has been relatively little investigation of germinal variation of the eyes of fishes, (2) that we have little warrant for supposing that such a remarkable peculiarity of the lens could arise as the direct result of the peculiar habit, and (3) that we cannot exclude the possibility that Anableps had a germinal or constitutional peculiarity of the eye which led it to take to its peculiar method of swimming at the surface, where the weakness might become a source of strength. It may be fairly said, perhaps, that this interpretation is just as far-fetched as the other. The fact is that we do not know.

Developmental Adaptations.—Besides *functional* adaptations by hundreds, say from warm-bloodedness to heliotropism, and *structural* adaptations, such as the viper's poison apparatus, or the Venus Fly-trap, among thousands, it makes for clearness to recognise another great group of *developmental* adaptations; which we mentioned in connection with life-histories. We refer to cases like the suppression or lengthening of an arc in the life-history in relation to particular surroundings or seasonal conditions. Thus in most freshwater animals, except insects, there is a suppression of larval stages which lessens the risk of the creatures being swept away. Similarly it might be said that the extraordinary rapidity of larval

development in insects like blow-flies, whose eggs are laid in flesh, is adaptive to the transient nature of that habitat; though it is not inconsistent with this interpretation to recognise the stimulating quality of the medium towards rapid growth. Or, again, the lengthening out of the ante-natal period—ending in viviparous birth—is an adaptation against the chances of death among delicate offspring. Even such subtle characters as the length of life, the age at which reproduction occurs, the localisation of the regenerative capacity, may be interpreted as adaptive, as we have sought to show else-

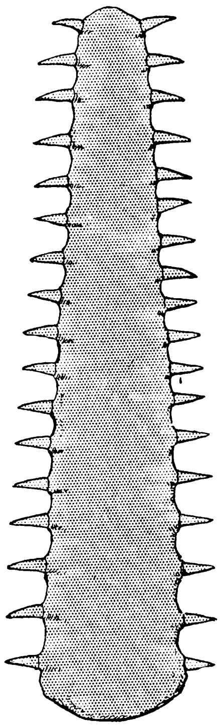


FIG. 189.

Saw of Sawfish (Pristis), an exaggerated prolongation of the anterior end of the cartilaginous skull, probably of most use as a weapon. From a specimen.

where. As to adaptations before birth, they are most appropriately referred to the previous groups—either structural or functional. Thus the diffusion of hormones through the mammalian placenta, from mother to offspring and perhaps vice versa, is an ante-natal functional adaptation. Similarly, the sheath of cartilaginous tissue that covers the saw of a sawfish embryo before birth, and prevents injury to the wall of the oviduct is a very useful ante-natal adaptation of structure. In a female sawfish (*Pristis cuspidatus*), 15½ feet long, Southwell found twenty-three embryos in the oviducts. Each of these had about nine inches of body-length and other five

inches of toothed saw; so that the use, and even necessity, of the sheath is obvious indeed.

ANOTHER MODE OF CLASSIFICATION.—On other lines, illustrated in many sections of this book, the numberless adaptations may be arranged according to the advantages which they help to secure or the difficulties which they meet. (*a*) Some adaptations secure the smoother and better working of the everyday functions of the body, such as the quality of warm-bloodedness. (*b*) Others are concerned with the quest for food, such as the peculiarly silent flight of the owl. (*c*) Others make for success in winning mates, like the odoriferous scales of some male butterflies. (*d*) Others help in successful parentage, like the pouch of most mother-marsupials. (*e*) Others again facilitate communal life, such as recognition-marks and kin-signals. (*f*) Some have their chief reference to the avoidance of enemies, such as cryptic colouration, death-feigning, autotomy. (*g*) Some are specially related to the different seasons of the year,

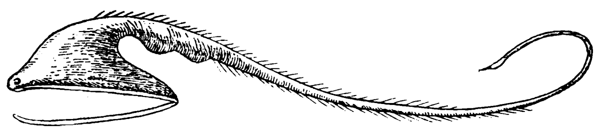


FIG. 190.

Abyssal Fish (Gastrostomus), with large head, relatively enormous gape, and locomotor body. Illustrating adaptation to the severe nutritive conditions of the deep sea. After Murray.

such as winter-blanching and summer æstivation. (*h*) Others again have their significance in connection with particular habitats, such as the tactility of Deep-sea animals. This is a kind of classification which the reflective student readily elaborates.

IMPERFECT ADAPTATIONS.—As the evolution of some structures and types has lasted for a relatively short time as compared with its age-long duration in other cases, it is not surprising that some adaptations are less perfect than others. The eyes of some marine worms are like prentice-work, those of Alciopids are very elaborate. Warm-bloodedness is imperfect in some mammals. The specialisation of the dentition in carnivores shows many gradations. It must be allowed that all adaptations are not equally perfect, and that there is a tax to pay on certain advantages.

It is doubtful, however, whether many instances can be found of the persistence of the positively disadvantageous, except during the period preceding the extinction of a type whose evolutionary momentum has carried it beyond the line of safety.

The enormous antlers of the Giant Irish Stag were probably disadvantageous masculine exuberances, and it is likely enough that the male narwhal finds its eight-foot long tusk somewhat embarrass-

ing. The process of moulting or ecdysis in crustaceans is hazardous and fatiguing, sometimes maiming and occasionally fatal; but these disadvantages are trivial compared with the advantages of the firm cuticular exoskeleton that forms a resistant armour and makes the jointed legs very effective levers and weapons.

There is an obvious danger lest a strong urge carry the organism too far; thus the over-sexed toads may be drowned by their sexual embrace, and the over-eager drakes may drown the duck in their orgasm. It is readily intelligible that an animal may suffer from the defects of its qualities.

In other cases the apparent mis-adaptation is due to some unusual change in the normal conditions of a tropistic or instinctive routine. Thus the moth flies into the artificial stimulus of the candle, and the lemmings sometimes swim with fatal persistence out to sea.

No doubt there are some difficult cases, but they are few and far between. A tree may fall when its exposure to the breeze becomes too great for the roots to stand, but the wonder is that this does not happen oftener. One must also ask how far the disproportion is due to artificial conditions of growth in plantations. In short, the evidence of "dysteleology", as Haeckel called it, is not convincing.

ORIGIN OF ADAPTATIONS.—This problem is but a special case of organic evolution in general, and we refer to the section dealing with the Factors of Evolution. What is said here must be very brief.

There are two main theories in the field—direct and indirect adaptation, using the word here to denote the process not the result. According to Lamarck's theory of direct adaptation, there has been a cumulative inheritance of individual modifications which arise under the influence of what he called *besoin et désir*, not necessarily so conscious as need and desire—and hence now called "organic urge", or *libido*, and by Bergson *élan vital.* There is as yet a paucity of positive evidence in support of this interpretation, plausible as it seems to be. Two obvious difficulties occur to the critic, (1) that hard chitinous structures like the instruments and weapons of insects are non-cellular and non-protoplasmic, and could not enregister the results of individual use and disuse; and (2) that some structures, such as the egg-opener in birds, or the often intricate coupling organs of some male insects, like dragon-flies, are used only once in a lifetime. But while the direct origin of an adaptation is excluded in cases like this, it does not follow that other adaptations may not have arisen in this way, especially in the case of structures much used through the organism's lifetime.

The Darwinian theory is that adaptations arise by the selection of germinal and heritable variations which have survival value by making their possessors appreciably fitter in the struggle for exist-

ence. Perhaps the greatest difficulty in the face of this theory is to suggest any reason for the origin of even incipient variations in the direction of such extraordinary fitnesses as the withered-leaf-like patterns on some butterflies, or the egg-opener of some larval insects that serves to cut the hard chitinous egg-shell and allow emergence. It is the first step that counts; and while we can understand the increase and elaboration of a structure by cumulative variations in the same direction after it got under weigh, it puzzles us often to imagine the beginning. "Some philosophers think that a faculty's granted, whenever it's shown to be very much wanted".

Osborn, Morgan and other evolutionists have pointed out that although individual adaptive modifications may not be transmissible, they may have indirect importance in evolution, by serving as life-preserving screens until coincident germinal variations have time to be established; and to this they have applied the term "Organic Selection"—not a very clear one. Thus an insect may be protected in colour because of what it eats until in the course of time it puts on cryptic colouration in some less direct way—variational, not modificational. As Gross puts it, in speaking of some instinctive activities: Imitation may keep a species afloat until Natural Selection can substitute the lifeboat of heredity for the lifebelt of tradition. But the metaphor is perhaps too suggestive of a shipwrecked world.

Whatever view be taken, it must include a recognition of the too frequently overlooked commonplace that organisms may share actively in their own evolution. As Prof. James Ward was wont to emphasise, an animal may seek out and even in part make its environment; it is not only selected, it selects; it acts as well as reacts. Environment acting on organism ($E \rightarrow f \rightarrow o$) —sustaining, stimulating, sifting—is one aspect of what we see; but the other is Organism actively functioning on environment ($O \rightarrow f \rightarrow e$)—changing, testing, choosing. The degree of this different sort of "Organic Selection" varies greatly with the type; but the use that an animal makes of an adaptive variation—say, the shape of its body—must have its effect on the success of that variation, e.g. on the rate of its racial establishment.

Caution re Adaptations.—We have given so many instances of adaptation, and of so many kinds, that it may seem we see them everywhere: so a word of caution is needed; indeed, two. First, that as adaptations arise in course of evolution, and as part of its progress, they may often have ample room for progress and for increase; and second, that adaptation is not by any means always so reciprocal as it looks, but may be only one-sided. Of this, to avoid criticisms which might lead us too far, and sometimes into

lengthy controversy, a specious illustration (not to say a spectacular one) may here suffice to indicate our caution.

People of normal sight in youth usually come to need spectacles about the age of forty-six, or so; and many, of course, need to start much younger, or even from childhood. Now since these accessory lenses (with their exact adaptation to the internal ones) are of very great importance for so many of the functionings of our lives, and these for both sexes, their vitally adaptive value is obvious, and their health-value also, as in many famous cases; and assuredly often we may say their survival-value as well. Now spectacles of all types are akin to pince-nez, i.e. are adapted to fit and rest steadily on our noses, if not even grip them. Here therefore might not an ardent (Martian) adaptationist say—must not this also be the adaptive origin of the human nose-bridge, as developed in course of survival of the fittest! And might he not even maintain and defend his argument much as do we mundane naturalists in many cases? For single developmental instance, see how, since babies have no spectacles, their nose-bridges are so commonly of little prominence! And for the corresponding phylogenetic argument, see how races not yet adapted to spectacles, as in Africa or Australia, have also often their nose bridges much less developed than are usually ours! Q.E.D. (?)

ARTIFICIAL ADAPTATION.—An illustration like the above is not simply jocular, nor even exceptional, far-fetched, or the like. On the contrary, it is but the example most obviously before our very eyes, of man's main line of external and artificial adaptation, both as and since he became truly human; and which, beyond internal organic evolution, as of mammalian progress, has given him his place and powers above the organic nature-forms he so increasingly dominates and controls. Recall how our spectacle-lens—fundamentally a monocle and not so long ago cut and polished out of natural quartz crystal—has thus arisen anew (and at the Renaissance!) out of the technique of the neolithic past (in which some observant worker may well have had a glimpse of its powers), and so carries us back into the history of tools. And as all these are extensions of our bodies, though generally of arms, hands and fingers, our lens is but a tool directed to reinforce the eye, instead of as more generally, however more indirectly, to satisfying the more clamant mouth. Such progresses of man are of course best considered with his own anthropology, discussed later: yet from the present biological point of view a term like Artificial Adaptation is convenient for appreciating such manifold survival values, and these for individual and society, whether up to guns and armour in war, or from lens (or waterdrop) to microscope in the laboratory of Peace-war, say the Pasteur Institute. Artificial Adaptation is thus the main field for Man's own Artificial Selection (and much of human

Sexual Selection too); and his civilisation is thus largely both the process and the resultant of his manifold adaptational urge towards artificially protecting himself further and further from the simpler processes of Natural Selection which have dealt so strictly with his progenitors, and of course can only too readily overpower his efforts still. As examples, two different disease-outbreaks in different parts of the world, and each described as new to medicine—are recorded in the same column of the newspaper current as we write; so what new adaptations, of cure and of defence, have their physicians now to seek and try for? Is not Hygiene, as well as medicine, very largely a matter of artificial adaptation?

DARWINISM OR DESIGN

The celebration by the Linnean Society in 1908 of the jubilee of that memorable evening when Wallace's and Darwin's papers, enunciating the principle of natural selection, were simultaneously presented and supported by Sir Joseph Hooker, will itself long be remembered by all who were fortunate enough to be present. For there, by rare exception to the swiftly changing course of human life, stood all three of the veteran leaders of British science, still hale in body and vigorous in mind, Wallace himself, Hooker and Galton.

We wish here to refer to Wallace's *World of Life*, not only as the expression of a great naturalist's mature convictions, but as a deliverance usefully contrasted with that of his magnanimous collaborator. Wallace had no lack of courage in raising the standard of uncompromising vitalism against Haeckel and Huxley. "Life must be antecedent to organisation, and can only be conceived as indissolubly connected with spirit and with thought and with the cause of the directive energy everywhere manifested in the growth of living things." Nay more, Wallace stood firmly to the end by his theses of the earth as cosmocentric, of life as unique, and of an overruling Mind, a Guiding Power. In his treatment of the objections to the Darwinian theory, he selected as the most important these three: (*a*) How can the beginnings of new organs be explained? (*b*) How can variations be co-ordinated? (*c*) How have developments beyond utilitarian requirements been produced? The first of these he boldly dismissed as imaginary; since for him there are no abrupt beginnings. For the second he was confident that the known amount of variation would amply suffice for the adaptation of any dominant species to a normally changing environment; while for the third he placed great weight on Germinal Selection, as an important extension of the theory of Natural Selection. Against Darwin's doctrine of Sexual Selection he remained consistently opposed: "The idea of all these

strange and beautiful developments of plumage, of ornaments, and of colour being primarily due to surplus vitality and growth-power in dominant species, and especially in the males, seems a fairly adequate solution of the problem." Further than this, he followed Woodward and the American palæontologists, in their insistence upon the recurrence of characters of old age in species towards the end of their geological range, and this from graptolites and trilobites, from ammonites and other molluscs, to the great reptiles of the less remote past, and thence up to the exaggeratedly sabre-toothed tiger or the heavy-hórned elk of comparatively recent times.

But this surely is "neo-Lamarckianism", "bathmism"—anything but orthodox and traditional Darwinism. Far from being an extension of it, it is surely a surrender to conceptions of life-progress combated by every other Darwinian and different altogether from those predominant in the past fifty years. True, they may be none the worse for that: but in Wallace we witnessed a veritable mutation of Darwinism, and no inconsiderable development of its co-discoverer and leading exponent.

Nor does Wallace's contrast with Darwin and Darwinians end here. Birds and insects are reviewed "as proofs of an organising and directing life principle"; and the famous thesis which concluded his *Natural Selection* in 1870—that "some of man's physical characters and many of his moral and mental faculties could not have been produced and developed to their actual perfection by the law of natural selection alone *because they are not of survival value in the struggle for existence*"—is not only restated, but extended to "the whole World of Life". "To afford any rational explanation of its phenomena we require to postulate the continuous action and guidance of higher intelligence; and, further, that these have probably been working towards a single end—the development of intellectual, moral, and spiritual beings." Paley surely could ask no more; and the elaboration of this thesis is astounding for a Darwinian, and contrasted against that "all-sufficiency of natural selection" of which we have heard so long. Indeed, Wallace seems to have thought of the progress of evolution, as conducted by a whole hierarchy of spiritual existences, from the Infinite determining the broad outlines of the universe, through descending series of angels, each allotted its appropriate division of the creative task! Here in fact is the Demiurgos of old: here appear anew "thrones, dominations, princedoms, virtues, powers"; but where now is the great goddess Natural Selection? At least how much of her old sufficiency for the production of new species remains to her?

Is there any way of reconciling such contrasted teachings? Shall we simply cling to one position or to the other, or with some, refuse faith to both doctrines, as offering us not only one mythology, but two? Not so: we are now on the threshold of a new period of life-

studies; a new conflict likewise, between physicist and vitalist theories, and by and by a new reconciliation also. We shall neither hold with the crudely physical materialism of one school, nor revert to the naive dualism of Wallace. But where shall we look for this reconciliation of physiology with psychology, no longer falling into mere necrology on the one side, nor leaping into phantomology upon the other? We need a bio-psychology which will incorporate all the work of the observer and the experimentalist; yet this complemented by a psycho-biology which will intepret the subtler problems and processes of evolution also, and by less far-fetched agencies. To this we shall return.

FURTHER ILLUSTRATIONS OF EVOLUTION

EVOLUTION OF THE FACE.—To the evolutionist everything is an antiquity, the past living on in the present, though often transfigured. For certainly it has been one of the great methods of Organic Evolution to make the new out of the very old. The trunk of an elephant is an elongated and mobilised nose, with the addition of a piece of the upper lip. The spinnerets of a spider are transformed abdominal limbs. Our Eustachian tube, leading from the ear-passage to the back of the mouth, is the same as the spiracle of a skate.

So, in regard to the human face, it is a new synthesis of ancient components. Even the Fundamentalist's face, as Mr. Beebe gleefully says, may be seen to be functioning with the third eyelid of a bird, the ear-point of a deer, the honourable scars of most ancient gills, and with the lip-lifting muscles of many a mammal when he sneers. It is not, of course, as if certain characteristics of ancient types had been pieced together as such, as one might add gadgets to a complex patent. It is rather that the evolving organism, like an unconscious artist, has used old materials in a new way, fashioning them into a fresh unity. Even to-day many a child looks out on the world with a face that was never seen before—so individual is it. Individual and yet an inherited mosaic, for as Prof. W. K. Gregory says, in the magic mirror of science proud man may see his own image—"a composite of an infinitely receding series of faces—human, pre-human, anthropoid, long-snouted, lizard-like—stretching back into the shadows of endless time." The story is well told in Gregory's recent book, *Our Face from Fish to Man* (Putnam's, 1929); and we wish, as an illustration of evolution, to indicate in brief compass the great events in the history of a structure that is always interesting, even when it is not beautiful.

At the outset we must avoid the popular search for some particular animal in the human face—the hero's eagle-eye or hawk-like glance, the villain's suggestion of a weasel or a rabbit, the walrus moustache

of the colonel and the simian supra-orbital ridges of the pugilist. A superficial trait catches the eye, and the whole face is summed up in an unfair adjective. Our question here relates to great changes that led from the skull of a fish to that of man. What were the most important architectural movements that led from the shark's humble cottage to the domed edifice of the human skull?

There is a sense in which some backboneless animals, such as wasps, have "faces"; and the old entomologists did not hesitate to speak of the insect's "frons" or forehead; but if we accept Gregory's definition of the face as "the food-detecting and food-trapping mask in front of the brain", there is nothing to be gained by trying to get further back than shark-like fishes. From these let us start.

The shark's face has all the essentials, such as mouth, jaws, eyes, nostrils, and brain-case; but it has very marked limitations, as is not surprising in a structure some hundreds of millions of years older than man's. A mouth—but turned to the under-surface of the head; eyes—but without eyelids; nostrils—but not externally quite shut off from the corners of the mouth; a brain-case—but with no forehead. Moreover, the shark's brain-case is one massive piece of gristle, so that it is like an old canoe dug out of a tree, while man's skull is like a modern rowing-boat, built up of a large number of separate pieces skilfully fitted together. In fact the shark's skull corresponds merely to the gristly foundations of the human skull.

Perhaps the first great advance was the development of bones, partly in the gristly brain-box itself (the "chondrocranium"), and partly plastered on to its surface from the enswathing skin and membranes. Man has twenty-eight bones in his skull, and in some form or other they are all to be seen in ancient fishes, now represented by the Mud-fishes and the Fringe-fins, which probably gave rise to the first terrestrial animals, the pioneer Amphibians, whose footprints are known in the late Devonian.

Many a fish, among the extant as well as among the extinct, has more skull bones than occur in man, and it must be understood that one of the lines of progress has been simplification. A good example may be found in the lower jaw, which has six bones on each side in most reptiles, but only one in mammals. One of the notable simplifications was getting rid of the protective bony mask, sometimes like porcelain, which covered the surface of the head in some of the old-fashioned fishes. When this was got rid of there was a promiseful clothing of the old surface with new muscles and with mobile skin. As Gregory says: "After producing a beautiful mask-face of great perfection and serviceableness, Nature started in to reduce and simplify it, and eventually to cover up this mask with tender, sensitive flesh." Various types have attempted mobilisation of the face, but it came to little before mammals. It has been well proved

that a thin wide band of muscle, that covers the neck and throat in reptiles, spread up over the primitive mammal's face, between the skull and the skin, and formed the muscles that move the lips and the external ears, and that close the eyes.

But we must not delay any longer in noticing what was going on inside the head—the relative increase of the brain in proportion to size of the whole, and especially the growth of the forebrain, which is the seat of the chief mental processes. In reptiles the brain is almost ridiculously small in proportion to the skull; it comes to its own in birds, and still more in mammals, except the most primitive types. This increase of brains was associated with a raising of the roof of the skull and the beginning of a forehead.

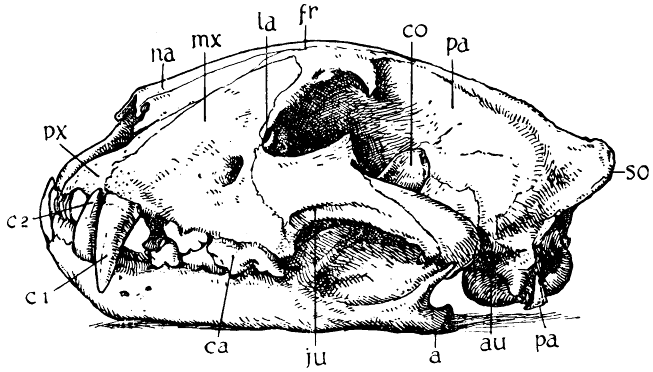


FIG. 191.

Bones of a Tiger's Skull. *so*, supra-occipital; *pa*, parietal; *co*, coronoid process of the lower jaw or mandible; *fr*, frontal; *la*, lachrymal; *mx*, maxilla; *na*, nasal; *px*, premaxilla; *c2*, canine tooth of lower jaw; *c1*, canine tooth of upper jaw; *ca*, carnassial or sectorial tooth of upper jaw; *ju*, jugal; *a*, angle of the mandible; *au*, ear-hole above the tympanic bulla; *pa*, paroccipital process of the ex-occipital. Among the salient adaptations of this skull may be mentioned—the posterior crests for muscle-insertion; the prominent zygomatic arch, formed by jugal in front and squamosal behind, for muscle-insertion; within this arch the spacious temporal fossa for jaw-muscles; and the teeth suited for carnivorous habits.

Another advance must be associated with the arboreal life of certain pioneering mammals, beginning with forms like the Tree-Shrews, the Spectral Tarsier and the Lemurs, and going on to monkeys and apes. The emancipation of the hand from being a support was associated with the reduction of the snout. An epoch-making increase in that part of the cerebrum that is concerned with vision, attention, delicate manipulation, and the like, was correlated with a forehead worthy of the name. The eyes were directed forwards, as snout decreased and forehead increased; the human face was within sight! There were, of course, other factors, such as the teeth, and the food they dealt with, the evolving voice and the rôle of lips and tongue in articulation, the moulding influence of variations in the hormones that regulate growth, the need for expressing

emotions—and that raises the whole question of the chiselling of the face from within. For every normal human face bears evidence of having been moulded by mind!

THE EVOLUTION OF THE HIVE.—We have already pictured the organisation of honey-bees, but now the question rises: How has all this wonderful hive-life come about? A difficult question indeed, if we seek a detailed and circumstantial answer; yet not so difficult to answer in outline, unless we raise the deeper question: By what factors has the evolution of social bees been advanced from stage to stage? Keeping to the first, the more descriptive question, we may notice, first of all, that just as solitary wasps have given origin to simple and these to more intricate communities of wasps, so hive-bees (Apis) have arisen from solitary bees through intermediate phases such as are represented by the familiar summer community of the humble-bee (Bombus).

We need not complicate the problem by inquiring what man has done for the hive-bee since he half-domesticated it in pre-historic times. He has certainly sophisticated the honey-bee since the days when he induced it to store its treasures in a hollow log near his dwelling, but we may be sure that he did not teach it sociality. The original honey-bees which became man's hive-bees were already social in the wild state, just as sheep were of course gregarious before they were domesticated. At the same time it must be admitted that man has left his mark on his bees, for he had to do with them before 3500 B.C. We know the price of strained honey in the time of the Pharaohs!

Before there were bees there were wasps, and the first chapter in our story is the divergence of bees (in the wide sense) from primitive wasps. These ancestors were somewhat like the burrowing Sphex, whose relatives we sometimes see disappearing into little tunnels on the roadside. This divergence of bees from wasps seems to have occurred at least twice, for entomologists distinguish two distinct lines—one leading to primitive bees like the waspish Prosopis, which makes silk-lined cells in bramble-stems, or in the earth, or in the mortar of walls; and the other line leading to the higher bees. So the first proposition, put bluntly, is that from solitary wasps there evolved solitary bees; and the evolution was associated with giving up carnivorous habits, and becoming wholly dependent on the nectar and pollen of flowers. A great many evolutionary steps have had to do with bread and butter. As Claude Bernard said, exaggerating a truth, evolution is a question of nutrition all through the ages. "Man ist was er isst" is another exaggeration of a substantial grain of truth.

The next step was the establishment of an immense variety of solitary bees, adapted to different kinds of flowers. It must be kept

in mind that of the 10,000 or so known species of bees, less than 500 are social, and these are all included in five genera. That leaves 9,500 different kinds of solitary bees, differing from one another in their tongues and hairs, nests and cells, and in their relations to the flowers they visit and the family they rear.

Among the solitary bees we may begin with those species in which the mothers usually die after egg-laying and providing food for their prospective young ones. They rarely survive to see the fruit of their labours. Many make nests quite apart from their kindred, but there are often anticipations of something else. Thus there may be gregarious nesting; there may be mutual aid against attack; two or more females may use a common hole of refuge. These are straws that show how the evolutionary wind once blew. How suggestive is a case where several females occupy separate nests, but make a common entrance tunnel—a sort of "common stair"! Even more significant are a few species in which the mother guards the eggs, and may even survive to see the offspring emerge. In some kinds of Halictus the fertilised females survive the winter and give rise to a generation of daughters in the spring. These are parthenogenetic, but their eggs develop into males and females in the autumn. The males die after fertilising the females, which hibernate as we have said. If the parthenogenetic daughters, produced in the spring, remained at home to help their mother, there would be a step towards a society. This step is actually taken in some very interesting South African bees belonging to the genus Allodape, where the daughters help their mother in provisioning and actually feeding the next brood. Thus arises the co-operative family!

But we must confess that a continuous story cannot be told at present, for Prof. W. M. Wheeler points out, in his *Social Life among the Insects* (1922), that the rudimentary societies of certain species of Halictus and Allodape cannot be regarded as the actual precursors of the social bees. They are interesting as stages, but they are not on the direct line of social evolution. The ancestors of the social bees remain unknown, though it cannot be doubted that they were, or perhaps are, among the solitary bees. There are three groups of social bees, the humble-bees (Bombinæ), the stingless bees (Meliponinæ), and the honey-bees (Apinæ). The first are the most primitive, the last the most specialised, while the Meliponines (with vestigial stings), that nest in hollow trees in warm countries, are strange combinations of the primitive and the specialised. They form permanent societies, but they make rather imperfect combs. They are the only social bees that are linked back to the solitary bees by the habit of rearing the brood of all three castes (queens, workers, and drones) in closed cells, never opened till the young winged bee creeps out.

The humble-bees of the Northern Hemisphere are of peculiar

evolutionary interest, inasmuch as they form temporary communities. A humble-bees' nest may include 100–500 inmates during the summer—old queen, young queens, workers, and drones; but only the fertilised young queens survive the winter. The worker humble-bees are precisely like the queens, except that they are smaller; the cells are essentially like those of solitary bees; the secretion of wax is rather primitive. In short, the humble- or bumble-bees represent a transition stage between the solitaries and the hive-bees. The interest of this fact is enhanced when we take account of von Jhering's observation that in South America the humble-bee colonies may be perennial. No one supposes that hive-bees were evolved from humble-bees; but that does not lessen the value of the fact that the colonies of humble-bees represent a stage through which the unknown ancestors of the hive-bees must have passed.

What made the hive possible? First, there was the establishment of particularly strong social instincts, which were wrought out in a long series of ancestors. Some of these instincts lead to an almost maniacal self-subordination, witness the brain-fatigue (microscopically demonstrated) and the short life of the summer workers. Second, there was the finer architecture of the honeycomb, for that facilitated storage on a large scale. Thus surviving the winter became the rule. With this, in the third place, there was associated a permanency of home, and in this connection we should take account of a persistently wild species like *Apis dorsata*, a nomad that builds a temporary comb where honeyed flowers are abundant, and abandons it when supplies are exhausted. Account must also be taken of the habit of swarming, of the puzzling device of rearing new queens when they are needed, and of the sinister massacre of the surviving drones at the end of the season. We are not forgetting that the whole evolution depends on wax, but the power of making this secretion is possessed by all the *social* bees, including Bombus.

Thus we pass from primitive solitary wasps to primitive solitary bees, and from solitaries to species that show anticipations of social life. Then, with an admitted hiatus, we begin again with bumble-bees, sometimes actually living without any workers, sometimes maintaining a permanent community, normally exhibiting social life in summer only. Thence, with another hiatus, we reach the species of Apis, which are not all on the level of *A. mellifica*, with its many virtues and its almost uncanny anticipations of state-socialism. All this is sketchy, but we have indicated the general lines of hive-evolution.

THE EVOLUTION OF THE SPIDER'S WEB.—No one can help admiring the web of the garden-spider and others like it, best seen at the height of summer, so effective in fly-catching, and so beautiful in structure; and some of those we see in autumn, be-diamonded with

dew or bespangled with hoarfrost, are what Walt Whitman called "masterpieces for the Highest". But along with our admiration there all the more arises the question: How did such an intricate and effective contrivance arise?

If the web of the Garden Spider, for instance, stood alone of its kind, what an insoluble puzzle it would be, especially as it is not nowadays what would be called an intelligent achievement. It is now the outcome of the spinner's instinct which requires no apprenticeship or individual learning, and is an inborn capacity for doing these apparently clever things. There may have been intelligence at work during its long-drawn-out racial evolution, intelligence, too, in testing the little improvements that emerged from generation to generation.

The method of evolution is to test all things and hold fast that which is good. But nowadays, at any rate, the spider has not to think over its web-making, unless there is some very peculiar situation. The web-making is part of the spider's instinctive routine; it is like a chain of reflex actions. Even if we say that it is suffused with vague awareness and backed by endeavour, experiments prove its routine nature. The spider's web illustrates hereditary skill, not individual intelligence. But our question is: By what stages did it arise?

The most primitive spiders are hunters and wanderers; and there can be no doubt that the antecedent of web-making was paying out a drag-line of silk. Whenever a spider is in a situation which demands careful movements, it pays out a drag-line, which often saves it from tumbling. When a spider is defying gravity by creeping back downwards along the roof of a room, gripping the whitewash with the toothed claws at the tips of its legs, there is always the risk of a flake giving way. But if that should happen, the spider has usually time to touch the roof with its spinnerets and to pay out a drag-line which allows it to sink down with dignity.

Sometimes it changes its mind, so to speak, and climbs up again, a feat that we have all repeatedly watched with amazement. It suggests a conjurer's trick. But the present point is that the evolution of the web must start from the drag-line habit.

The primitive spider probably lived in a hole, made comfortable with a lining of silk. Nothing would be more natural than an accumulation of drag-lines around the mouth of the retreat. These would trip up and entangle passing insects; so what began somewhat unintentionally would by its utility suggest its own extension and elaboration. The most primitive spiders, which have persisted almost unchanged for millions of years, since the Carboniferous Age, make a home consisting of "a tunnel-like hole lined with silk, with the edge of the lining drawn out all round the mouth in a fringe".

In his fascinating *Biology of Spiders* (1928), Mr. Theodore H.

Savory suggests that the primitive type of web consisted of an expansion of the tube which lines the burrow. The vibrations caused by tripping insects would be felt by the spider lurking in the hole. Almost every stone wall in Northern France shows a large spider (*Segestria florentina*) living in such a retreat.

As a gaping hole is rather a temptation to inquisitive aggressive creatures, such as centipedes, it is easy to understand the advantage of making a trap-door as many spiders do. But this was a later achievement. The theory of deriving a web from an extension of the mouth of the silk tube lining the burrow seems shrewd; we should like to add the suggestion that some of the rough-and-ready webs may have arisen, apart from any tube, from tangles and snares of silk among the grass and herbage.

The next stage in evolution was the cobweb, familiar in the house-spiders, Tegenaria. There is still a silken tube for a resting-place, but the extension of the fringe is almost confined to the lower edge, which is spread out horizontally as a hammock-like sheet. Cobwebs are not confined to indoors; the gleaming white sheet spun by *Agelena labyrinthica* is common on gorse bushes in autumn. Supporting the hammock there are mooring threads, and as insects are apt to strike the upper ones, an extension of these might well be the next step in evolution.

When the sheet is raised to a more or less exposed situation, where flying insects are more likely to blunder into it, the tube has to be dispensed with; and the spider takes up its position on the under-surface of the web, as may be seen on every bramble-bush. But an exposed web is apt to be torn by the wind; and thus we can understand that many spiders prefer to do one of two things—to weave small sheets near the ground, where we often see them glistening, or to dispense with the sheet and trust to a tangle of lines in all directions.

Some regard these tangles, familiar in the hedges, as primitive webs in the making, but Mr. Savory has given reasons for interpreting them as degenerate rather than primitive, simplified rather than simple.

The climax is the orb-web, familiarly illustrated by the garden spider's work of art. The characteristic features here are: (1) the reduction of the net to two dimensions, (2) the uniform covering of the area by the simplest sequence of movements, and (3) the making of a net that is unified, so that it can be held relatively taut, and so that vibrations are readily transmitted by a special thread to where the spinner lurks.

IMPERFECTIONS IN ANIMALS

In a famous deliverance Walt Whitman maintained that all animals are "equally perfect". But this is not borne out by

comparison, and it is on general grounds likely that a type that began many millions of years ago may attain to greater perfection than is shown by one of modern origin. No doubt an animal of ancient origin may remain unprogressive if the conditions of its life are unstimulating; no doubt the higher animal starts on the shoulders of its predecessors; but it seems good sense to expect, on the whole, greater finish and harmony in races that have been subjected for untold ages to severe winnowing. If we take imperfection to mean lack of harmony in the internal working of the body, and lack of fitness in reactions to the environment, what evidence is there of this in the everyday life of animals? In a system where the fit has always survived—fit even to dunghill conditions—can there be much in the way of unfitness? This is a question which has been recently discussed by Prof. W. E. Ritter, in his interesting book,

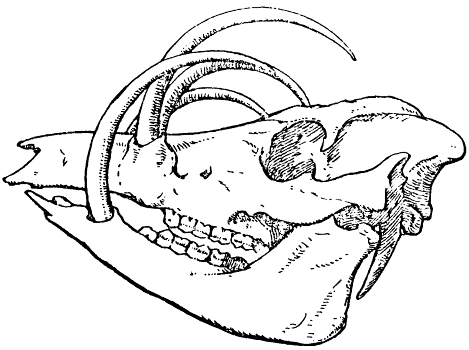


FIG. 192.

Skull of Babirussa, showing the exaggerated growth of the tusks—the upper and lower canines. From a specimen.

Animal and Human Conduct; and, taking a particular kind of misadaptation, we wish to direct attention to some of his evidence that animals often do themselves much injury. We do not believe it.

During heavy rain in some American cities earthworms come to the surface of the side-walks and are trampled on in thousands. Various reasons have been given for this behaviour—e.g. that the earthworms don't like to be drowned, but in any case the facts show that an ancient type of action may persist in conditions where it is disastrously inappropriate. But it does not seem to us to be a very serious indictment of Nature's regime to say that the enregistration and entailment of reactions that are usually profitable may lead to fatality in such artificial circumstances as the city of Washington affords.

Vernon Kellogg gave some years ago a vivid description of the terrific holocaust of mayflies around the arc-lamps at Lucerne. These ephemeral insects have a sub-aquatic larval life of two or three years, and an adult reproductive aërial life rarely exceeding

two or three evenings. Some of them never see full daylight; and in Lucerne, like the moths to the candle, they are "drawn" to the lamps in myriads. This obligatory movement or tropism does not concern us at present. The mayflies' wedding dance becomes in lamplight a dance of death; and for 30 or 40 feet underneath one of the Lucerne lamps the ground was covered one or two inches deep with their delicately beautiful bodies. But what can we say save that a way of life which is effective for the race in natural conditions may be dismally inappropriate in artificial circumstances? During the ages when these old-fashioned insects were being evolved there were no brilliant lights to be guarded against. Nature must be acquitted.

Passing to a higher level, Prof. Ritter gives examples, familiar to most of us, of the distracted way in which birds often hurt themselves in trying to escape from a room. They fly in through the widely open lower half of the window; they find themselves in a very strange environment; they are torn by confused impulses—including a desire to escape from their would-be friends—and they dash themselves to death against the upper pane. Since even a clever man may walk up against a partition of plate glass, we cannot profess to be much concerned with the bird's imperfection. We can balance against it the way in which a bat, entering the room, will fly under a chair without knocking against anything, and will re-discover the window by which it entered in the darkness. As to the blackbird's savage fight with its own reflection, we must remember what a puzzling thing a mirror must be. Even the big-brained chimpanzee in Köhler's experiments tried persistently to grab the grimacing fellow on the other side of the looking-glass. We have watched a fox-terrier, belonging to a highly intelligent race, fighting furiously and for a long time with his reflection in a shallow trough of water, and getting well soused in the process.

Ritter maintains that birds contribute to their own undoing by the imperfection of their adaptations. The resplendent O-O (*Moho nobilis*) of the Hawaiian Islands calls attention to its presence by its often repeated loud call. The Hawaiian barnacle-goose has become a terrestrial bird, and it is now courting destruction by rigidly returning to the same breeding places year after year. This is the more disastrous because when the goslings are being led around by their parents the former cannot fly because they are too young, and the parents cannot fly because they are moulting. Not many years ago the Passenger Pigeon seemed to have a stronghold in North America. It occurred in such multitudes that their flights eclipsed the sun and the air smelt of pigeon for miles and for days. But there came an extraordinarily sudden check to its numbers and prosperity; in a short time the Passenger Pigeon became an extinct species. The reasons for this are far from being clear, but

Ritter maintains that the bird itself was in part to blame. It was outrageously gregarious, sometimes breaking down trees with the weight of its numbers. It often nested too early, before the snows were over. It committed race-suicide by over-population. "While upon civilised man there primarily rests the responsibility for this zoological tragedy, the birds themselves must be recognised as having been closely accessory." But even in these cases we cannot feel convinced that the indictment is quite fair when man is in the plot. For man is an agent of unpredictable ingenuity and with an effrontery of ruthlessness, and it is hardly a misadaptation to be baulked and baffled by him. Is it really a misadaptation in the gentle Franklin Grouse that it composedly watches man's approach to within a few feet? "One sat sedately on a limb while a revolver was emptied at her." What imperfection!

Other alleged instances of self-injury are found among mammals. Hornaday mentions five causes that led to the practical extermination of the American bison, and while four of these point to man's ruthlessness and shortsighted greed, the remaining one is "the phenomenal stupidity of the animals themselves and their indifference to man". Ritter says: "We are obliged to conclude that the nearly complete extinction that has befallen the once widespread, abundant, and valuable species of elephant-seals is due in no small degree to the stupidity of the creatures themselves." But it must be remembered that the elephant-seal's experience of man was not more than a century old; and that a tradition of timidity is not to be expected in giants. If animals have not known fear for tens of thousands of years, is it much of a misadaptation that they remain unafraid when some men intrude from a boat?

We are not impressed by stories of mammals smothering one another in a panic, of a pony becoming stiff with shock at its first meeting with a motor-car, of baboons over-eating themselves, or of a Rhesus monkey clinging for five weeks to the shrivelled remains of her offspring. If these are the best instances of misadaptation, the indictment is not very serious.

Yet what of the suicide of the lemmings, which, obeying their instinctive impulse to go straight on until they find pasturage, continue their mass movement into the sea and are drowned in large numbers. But the trekking instinct often works well, and it should be a rule in the study of animal behaviour not to infer stupidity or misadaptation from occasional instances of an instinct proving fatal. When a piece of routine has become thoroughly enregistered and instinctive it is difficult for intelligence to take the reins.

We do not maintain, as we hinted at the outset, that all adaptations are perfect, but we do not think that the evidence of serious imperfection is strong. Against the imperfections that evolution has

not had time or opportunity to remedy we must reckon the frequency with which animals can adjust their ways to novel conditions of life. But if these habit-changes are studied it will be found, we believe, that in the great majority of cases the changes affect not instinctive promptings or racially enregistered routine, but ways that have an intelligent or associative basis. Predominantly instinctive animals tend to become stereotyped; predominantly intelligent animals remain educable.

SUMMARY AS REGARDS VARIATION AND HEREDITY

1. Organic Evolution is a natural process of racial change in a particular direction, in the course of which new forms emerge and are established, alongside of or in place of the originative stock.

2. The factors in organic evolution may be distinguished as (*a*) originative or variational, (*b*) hereditary, (*c*) selective, and (*d*) isolative. (*a*) The originative factors induce novelties or new departures of some sort, which form the raw materials of possible evolution, whether progressive or retrogressive. (*b*) The hereditary relation determines whether new features are continued on, like the old-established features; it determines the proportion of their recurrence (if any) in the offspring. If a new variation is not entailed on some of the progeny, it cannot be of direct value in evolutionary change, though it may be of individual import during the lifetime of its possessor. Thus heredity is a condition of evolution, and even if there were no progressive evolution there would still be heredity. (*c*) In the course of the struggle for existence, which includes all the reactions that living creatures make to environing difficulties and limitations, there are many forms of selection or sifting which secure some greater degree of survival or success for those variants that are in some respect or respects fitter than their fellows. The discriminate or differential sifting or elimination may lead to the immediate death of a novel variant, or it may simply involve a shorter life or a smaller less successful family. But the logic of the process is always the same—the relatively less fit tend to survive, and thus a species slowly changes. (*d*) The process of raising a new group of similar variants to the level of a true-breeding stable variety or sub-species, and eventually to the level of a discontinuous species, not readily fertile with its relatives, is helped by numerous forms of isolation (geographical, seasonal, habitudinal, etc.), which narrow the range of inter-crossing and bring similar forms to breed together. Thus there are the four outstanding factors—changing, entailing, sifting, and singling (variation, heredity, selection, and isolation).

3. Variations are novelties distinguishing offspring from their

parents and ancestors, and often distinguishing one member of a family from another. They may affect quantitative characters—a little more of this and a little less of that, or they may be qualitatively novel, e.g. some new constitutional or biochemical feature; they may be structural or functional; and they are often negative as well as plus. Some may be described as changes in the rate and rhythm of metabolism; others are lengthenings out or shortenings down of arcs on the life-curve, e.g. an extension of youth or a shortening of mature activity. A new departure may be progressively accentuated from generation to generation, and persistence on one line for a succession of generations is said to illustrate orthogenic change. When a novelty arises abruptly without intergrades connecting it with less marked but similar features in the parents or ancestry, it is called a mùtation, and may be large or small in amount; it turns out to be independently heritable, without blending or breaking up, and illustrates Mendelian inheritance. Other variations, less clear-cut, intergrading in amount, are often called fluctuations. They do not "mendelise".

4. New departures that continue hereditarily from generation to generation, and may be increased by selection, are usually regarded as due to changes in the constitution of the egg-cells and sperm-cells, or as the outcome of the fertilisation of the egg-cell by the sperm-cell. They are briefly spoken of as *germinal variations*, and the modern idea, which Darwin did not clearly realise, is that the changes which crop up in the developing body are the expressions of antecedent germinal permutations and combinations, gains and losses, disturbances or enhancements. It is because of their germinal origin that true variations tend to be continued on to the next generation, just like the well-established inheritance in general. This begetting of like by like depends on the fact known as the continuity of the germ-plasm, an idea particularly associated with Weismann. The general idea, then, is that the fluctuations and mutations that form the raw material of further evolution have a germinal origin.

5. But in the present book the thesis is also stated that the organism is not restricted in its varying to the time when it is implicit in the one-cell phase of its being, but may vary constitutionally later on, e.g. by becoming more nutritive or more reproductive, by becoming more foliar or more floral, by shortening or elongating the axis in flowering plants, by emphasising anabolism or katabolism, and so forth. Yet to the more Weismannian author it appears that these apparently somatic variations are *au fond* germinal variations which express themselves within certain old-established limits or trends of development and metabolism. The explicit organism varies along prescribed constitutional lines, but the impulse and bias of the varying is germinal.

6. Among the novelties which crop up among organisms, in some plastic types more than others, e.g. among plants more than among mobile animals, there are numerous somatic changes that can be experimentally proved (too often only surmised) to be the direct results of peculiarities in external conditions and mode of life. They are directly impressed on the body of the individual as the results of peculiarities in environment and nutrition, use and disuse; and they have unfortunately received the name "acquired characters", meaning that they are directly impressed on, or acquired by the body of the individual. They are more usefully called "somatic modifications", and may be defined as changes directly impressed on the individual body as the result of peculiarities in surroundings, food, habits, and endeavours, and so transcending the limits of organic elasticity that they persist even after the inducing conditions have ceased to operate.

7. It is generally admitted, e.g. by Weismann, that deep external changes, e.g. of climate, may so saturate through the organism that they influence the germ-cells as well as the body, and may thus have an effect on subsequent generations, though not necessarily the same effect as that expressed in the original modification. It is also admitted that deep influences from without, e.g. poisoning or starving, a tonic environment or generous nutrition, may in a general way decrease or increase the vigour of the germ-cells, and thus of the offspring. It is also admitted that outside influences may serve as trigger-pulling, liberating stimuli which induce new germinal variations. Moreover, a modification may serve as a life-preserving individual change for successive generations until, it may be, a germinal variation in the same direction has opportunity to occur and time to establish itself.

8. There seems to be as yet very little convincing evidence that a somatic modification can be transmitted or continued on to the next generation as such or in any representative degree; but it is too soon to deny the possibility. The cases pointing towards admitting the possibility have been illustrated in the text; they are mostly of a difficult and unusual type.

9. The whole question is very difficult—much more difficult than is sometimes hurriedly supposed—and it is of great theoretical and practical importance. A few misunderstandings may be referred to. (*a*) There is little use in saying that every novel character must have been acquired sometime, for the word "acquired" is here used ambiguously. That a novelty may be established as a racial character is obvious; the question is whether this is ever true of novelties that begin as extrinsic modifications, not as germinal variations. (*b*) It is certain that most characters of living creatures require an appropriate "nurture" if they are to develop aright; but the question at issue concerns changes of body that are impressed by *peculiarities* in

"nurture". (*c*) It is rightly said that an evolution theory, dealing with the ascent of life, is unthinkable if it takes no account of the individual's experience and changing endeavour. But the rôle of the individual is to play its hereditary hand of cards, to put its mutations and fluctuations to the test in the struggle for existence—a test which determines survival. A change in the intensity of endeavour may readily arise as a germinal variation—by hypothesis heritable. (*d*) In cases where particular species are known only from uniform surroundings, all the members with similar diet and habits, it is quite possible that some of the constant specific characters, on which the systematist relies, are *modificational.* They re-appear uniformly because they are re-impressed on each successive crop. Experiments are urgently required in this connection. (*e*) No biologist has any doubt as to the importance of modifications for the *individual,* or as to the *general* plus or minus effect that some of them may have on the vigour of the stock.

10. Novelties or new departures in organisms may be classified as follows:

A. SOMATIC MODIFICATIONS.
   Degree of transmissibility uncertain.

B. GERMINAL VARIATIONS.
   (1) Mutations, arising abruptly, very heritable, mendelising.
   (2) Fluctuations, quantitative, with intergrades, often heritable, tending to blend.

From these some would separate off germinal variations induced by nurtural peculiarities (e.g. changes in terrestrial radiation!) which influence the germ-cells through the body, or through modifications effected in the body but evoking other changes in the offspring.

As stated already, one of the authors of the present volume holds by the view that an organism need not cease to originate novelties after it passes beyond the one-cell phase of its being. A flowering plant may become more floral, and another may vary in the direction of grassiness; in one type the axis may be shortened down, while in another it is lengthened out; one animal may tighten its bow of endeavour and another relax it; one type may prolong its embryonic phase and another its larval period. Such organismal or constitutional variations, based on deeply rooted, old-established alternatives, e.g. of metabolism and development, may somehow repercuss on the germ-cells and thus affect the succeeding generations. This is a subtle Neo-Lamarckism.

11. Wherever there is among animals, e.g. in ant-hill or bee-hive, something of the nature of a social heritage, or permanent products, or a tradition, or a lasting change of the environment, or an external system of inter-relations, then variations will be subtly tested

(scrutinised, as it were) in relation to what has been established, those that are congruent being favoured, those that are incongruous being handicapped.

12. As to the causes of germinal variations, our ignorance remains, as in Darwin's day, "immense"; yet some illuminating suggestions have been made:

(*a*) In the early history, maturation divisions, and fertilisation-amphimixis of the germ-cells, there are many opportunities for novel permutations and combinations in the chromosomes which carry many (if not all) of the hereditary initiatives (representative factors or genes). In the phenomenon of "crossing over", in which there is exchange of parts between two adjacent chromosomes, there are obvious possibilities of new arrangements. So in the meiotic division which reduces the number of chromosomes by a half during the maturation of egg-cell and of sperm-cell. So again in the pooling of the paternal and maternal hereditary contributions in the process of fertilisation.

(*b*) The germ-cells contain a very intricate equipment of hereditary factors, implying an inconceivable chemical complexity; and it may well be that changes are induced (1) by alterations in the nutritive stream of the parental body, wherein the germ-cells do not live a charmed life in spite of their segregation, or (2) by modifications induced in the parental body, or (3) by deeply saturating environmental changes, such as change of climate or in irradiation with gamma rays.

(*c*) A germ-cell is an implicit organism; it is richly endowed with ancestral contributions; it is alive. So perhaps its variability is in part intrinsic or spontaneous or creative—as primary a quality as irritability. Moreover, the germ-cell is an implicit mind-and-body organism, and it may be that part of the difficulty of the problem of the origin of the new, is just that it is a psycho-biological phenomenon.

13. There is little usefulness in speaking of variations as "fortuitous", unless we mean to emphasise the fact that they are usually unpredictable; or unless we mean, as Darwin meant, that they are often the outcome of a complex of imperfectly known pre-conditions; or unless we mean that the quantitative amounts of a variation occurring at the same time in a species will show when plotted out the well-known curve of frequency; or unless we mean that there may be great diversity in the progeny of the same two parents. In a deeper sense a variation is anything but a chance affair, for it is a re-arrangement of parental or ancestral items, it is the outcome of a pre-established association of genes, unified at the beginning of each new life in the system of the mature germ-cell or of the fertilised

ovum. A new variation must be consistent with what has gone before; bizarre additions to the germinal architecture are very improbable, though it sometimes happens in experimental breeding that there is an occurrence of non-viable or lethal combinations of hereditary factors. In Wild Nature the occurrence of pathological variations seems to be exceedingly rare. There is some fortuitousness in the process by which one member of a pair of homologous chromosomes is given off in the first polar body of a maturing ovum, or in what decides which of two kinds of sperms enters the egg; but the smallness of the fortuity here may be inferred from the fact that it is in the reducing or meiotic division that the phenomena of Mendelian Inheritance find their explanation. The fact that the number of chromosomes in a series of related species sometimes forms a numerical series, like 7, 14, 28, 56 in roses, strongly counters the mistaken impression of fortuitous. And if the raw material of evolution is but slightly fortuitous, the same may be said of the selection mill, for it has its foundations in a long-established, subtly inter-related *systema Naturæ*. The struggle for existence may discriminate between a Shibboleth and a Sibboleth variation, but its operation is anything but fortuitous.

14 An important general fact is expressed in the phrase "correlation of variations"—an idea which Darwin emphasised. Certain new departures hang together; they may be diverse expressions of one mutant gene, or of a new gene, or of certain genes which always occur close together in a group. Just as an inborn disease may have many different expressions in different parts of the body, so it may be with an integrative germinal variation. This may sometimes be the case when a novelty is still in its initial stages and not large enough to be caught in the selection-sieve; yet it may be selected because it is associated with an older and larger variation that has become well established.

15. Heredity may be defined as the flesh-and-blood relation of genetic continuity between successive generations, such that a specific organisation is continued on, "like tending to beget like".

16. The inheritance is all that the organism is or has to start with in virtue of its hereditary relation, and the vehicle of the hereditary initiatives (called "factors", "determinants", "genes", etc.) is mainly (most biologists say wholly) in the chromosomes of the nuclei of the germ-cells. It is still premature to say that part of the inheritance may not be carried by the extra-nuclear protoplasm of the germ-cells. The genes are not visible, yet they can be indirectly measured and mapped! They seem to lie in a linear order along each chromosome.

17 As a chromosome is in life a very fluid structure demarcated by a film (though it may appear compact and well defined after fixing and staining), we must not think of the initiatives or genes as

like ultra-microscopic billiard-balls. We dare say little more than this—as yet, that they are protoplasmic differentiations causally related to particular characters into which they develop in the offspring arising from the fertilised egg-cell. But one gene may affect several characters of the offspring, and one character of the offspring is often the outcome of the co-operation of several genes.

18. The largest fact as regards heredity is "the continuity of the germ-plasm". That is to say, when a fertilised egg-cell is developing into an offspring, some of the germinal material is kept apart in completeness and generality, not sharing in body-making or differentiation, but retaining the complete hereditary equipment of the fertilised egg-cell. Such, more or less clearly, segregated germ-cells form the reproductive organs and their cells, so that in the beginning of the *next* generation there is precisely similar material to start with. There would be complete hereditary resemblance, if it were not for the causes, already considered, which evoke variations. When body-cells or somatic cells retain, in spite of their division of labour, a complete and uninhibited equipment of genes, there are the well-known possibilities of asexual multiplication and regeneration.

19. Development is the individual realisation of the inheritance. The implicit becomes explicit, the latent patent, the invisible visible. Out of the apparent simplicity of the fertilised egg-cell (in all ordinary cases) there is developed the obvious complexity of the organism. But normal development always implies an appropriate "nurture" (e.g. food, oxygen, moisture, space, exercise); and a developed character is a function—a product—of the inherited "nature" and the environing "nurture".

20. Experiment shows that the egg-cell and the sperm-cell contain a complete equipment of the specific characters; and they contain the same number of chromosomes, which is half the number $\left(\frac{n}{2}\right)$ which is characteristic of the species in question (n). The halving of the number is effected during the maturation of the germ-cells, prior to fertilisation. But as regards the genes of novel characters or individual characters, not part of the normal equipment of the species, they may be carried in the egg-cell, but not in the sperm-cell, or vice versa, or by both, or by neither. Thus when albinism, or the thorough absence of pigment, occurs in an offspring, it means that the genes for pigmentation have dropped out, in the course of pre-fertilisation changes, from the particular ovum and from the particular spermatozoon, that unite.

21. When two members of a species pair, the resulting offspring may show:

(*a*) a replica of the two parents, if they were practically indistinguishable—complete hereditary resemblance;

(*b*) a blend between the two parents, if they differ in the amount of a fluctuating character, such as the length of the pendent ears of two (varieties of) lop-eared rabbits; or the characters of half-bred sheep resulting from crossing Leicesters and Cheviots;

(*c*) a coarse-grained mixture, when a paternal characteristic is expressed in one part of the body, and a corresponding maternal characteristic in another part, as in a piebald pony;

(*d*) a reversionary rehabilitation of an ancestral characteristic which has been for several generations latent, while in other features the offspring may show (*a*) or (*b*) or (*c*);

(*e*) a characteristic feature of one side of the house only, uninfluenced by its absence or difference in the other parent—the first step in Mendelian inheritance, which is of very frequent occurrence; or

(*f*) something quite novel and unpredictable—a mutation. For the hereditary relation is such that while it reduces the risks of variability, tending in the main to the persistent continuance of a specific organisation, it by no means precludes the outcrop of variations. Variability is antithetic to complete hereditary resemblance, yet its possibility is implied in heredity.

22. Typical Mendelian Inheritance may be briefly described as follows:

If a cross is effected between two organisms belonging to true-breeding strains of a species, differing in a crisp, well-defined unit character, such as gigantism and dwarfism in garden peas, or banded and bandless shells in wood-snails, or horns and no horns in cattle, the offspring will take after one parent only; and the character that is developed is for that reason called *dominant*, while the one that is not developed is for that reason called *recessive*.

Parent with D × Parent with R*
Result the offspring
show only the
D character
D(R)

The reason for putting the R character in brackets is that it has not really disappeared, as subsequent breeding shows, although it is unexpressed.

If the hybrid D(R) offspring are inbred, or bred with others of the same history, the second filial generation will show both parental types, as regards the character being tested. Out of every four, three on an average will show the dominant character, and one the

* Or it may sometimes be absence of D.

recessive character. But of the three showing the dominant character, one will be "a pure extracted dominant", yielding only dominants when paired with another like itself, while the other two, the "impure dominants" will, if inbred, yield pure dominants, pure recessives, and impure dominants again, in the average 1 : 2 : 1 ratio.

$$\begin{array}{ccccc} & & D(R) \times D(R) & & \\ & & \downarrow & & \\ 1\,DD & + & 2\,D(R) & + & RR \\ \downarrow & & & & \downarrow \\ DD & & & & DD \end{array}$$

The "extracted pure recessives" will yield only pure recessives if inbred or bred with others of similar history.

A giant pea crossed with a dwarf pea yields giant offspring only. Tallness is dominant, shortness is recessive. The hybrid offspring (F^1), left to self-fertilise, will yield in the second filial generation (F^2), 25 per cent. pure talls, 25 per cent. pure dwarfs, and 50 per cent. impure talls.

The reason for the precise ratios (often closely verified in an average of largish numbers) is that the germ-cells of the hybrids (F^1) become segretated (in the maturation divisions) into two contingents, one set with the gene for the dominant character, and the other set with the gene for the recessive characters. If fertilisation is fortuitous, an egg-cell with a D gene may be fertilised by a sperm with the D gene, or by a sperm with the R gene, and an egg-cell with an R gene may be fertilised by a sperm with the R gene or by a sperm with a D gene. Thus the results must be in the ratio 25 DD : 50 D(R) : 25 RR. When the two parents differ in more than two contrasted characters the formula will, of course, be more complicated.

The complete scheme for monohybridism—a pair of contrasted but corresponding features (or allelomorphs) stands thus:

$$\begin{array}{lccccc} \text{Parents} \quad \ldots \quad \ldots \quad \ldots \quad \ldots & & & D \times R & & \\ & & & \downarrow & & \\ \text{First Filial Generation} \quad \ldots \quad \ldots & & & D(R) & & \\ & & & \times\times & & \\ & & & D(R) & & \\ & & & \downarrow & & \\ \left.\begin{array}{l}\text{Second Filial}\\ \text{Generation}\end{array}\right\} & \begin{array}{c}25\,\%\\ DD\end{array} & + & \begin{array}{c}50\,\%\\ D(R)\end{array} & + & \begin{array}{c}25\,\%\\ RR\end{array} \\ & \times\times & & \times\times & & | \\ & | & & \downarrow & & | \\ \left.\begin{array}{l}\text{Third Filial}\\ \text{Generation}\end{array}\right\} & 100\,\%\ DD & & (25\,DD + 50\,D(R) + 25\,RR) & & RR\ 100\,\% \end{array}$$

If a normal mouse is paired with a waltzing mouse, all the offspring are normal; and we say that normal locomotion is dominant over the waltzing peculiarity. If the hybrid offspring (F^1) are inbred, their offspring will show 25 per cent. pure normals, 50 per cent. apparent normals, and 25 per cent. pure recessives. One of the last might be certificated as a pure waltzer although both its parents seemed normal, and one of its grandparents was normal through and through. An extracted recessive will breed true to waltzing as long as it is paired with others like itself.

23. Of far-reaching importance is the idea that an inheritance is (in part at least) a congeries of unit characters which illustrate Mendelian inheritance, and the fact that mutations have this non-blending, non-fractionating quality. It may be pointed out that an apparent blending, as in a mulatto's skin, may arise when the character in question is due to several minor characters which may be dominant in one parent, recessive in another. Similarly, if human stature be determined by factors for the lengths of different parts, which are hereditarily independent, the illusion of blending may be produced by a mingling of various items from the two parents. Or again, there are said to be eight factors determining the colour of a wild rabbit's fur; according to the number that drop out in domesticated breeds, various colours result; a subsequent re-combination of these in uncontrolled pairing results in a wild rabbit pattern, which is no longer a mysterious "reversion".

24. In all cases, whether we are dealing with variation, heredity, selection, or isolation, we must keep in mind the commonplace that the central fact is the living organism, an agent, often obviously psycho-biological, often certainly able to share, to good purpose, in its own evolution.

DIFFERENT KINDS OF EVOLUTION

Evolution is one of the badly over-worked words, like "force", "instinct", or "value". It means a process of Becoming, but it is applied to various orders of facts which have very little in common, either as regards the material evolving or the way in which the evolution comes about. We hear of the evolution of a solar system, the evolution of matter, the evolution of religion, the evolution of the chemical elements, the evolution of man, the evolution of language, the evolution of scenery, the evolution of the horse, the evolution of mind, the evolution of plants, the evolution of sex, the evolution of society, the evolution of species, the evolution of evolution theories, and so on. When processes that are different are called by the same name, there is bound to be confusion; and it is more than verbal. We venture to make some simple suggestions which, if accepted, would lessen the confusion.

(1) Cosmic "Evolution" or Genesis.—In the inorganic domain there has often been a process of Becoming which led from a nebulous mass to a stellar or a solar system. How this came about does not concern us here; but some improved edition of the Nebular Hypothesis of Kant and of Laplace is plainly being elaborated. But such a mode of Becoming as the origin of our planetary system from knots on spirally twisted arms drawn out from the central sun is obviously very different from the Organic Evolution of, let us say, mammals. For in the cosmic Becoming there is nothing like a sequence of generations; and hence nothing quite like sifting or selection as regards the main masses concerned. There is, no doubt, some loss of Energy-Matter into space, but on the whole it is the same material throughout which is the subject of rearrangements or differentiations. We cannot say that there was no advance in the cosmic process, for the establishment of the earth-knot opened up possibilities—of life, for instance—which were not recognisably present in the primeval nebulous mass. Nor should we like to say that the cosmic Becoming was entirely different from Organic Evolution in being inanimate. What is certain is that as long as no question is raised as to the origin of living organisms, not to speak of living and thinking organisms, the advancing concepts of the mathematical and physical sciences should suffice for the description of what occurred in the establishment of our solar system; though, of course, the relativity theory, and other advances are proving this a much more intricate matter than it seemed a generation ago. In any case, the cosmic process should not be called by the same name as the organismal process; and our suggestion is that it might prove convenient to speak of the *Genesis* of the solar system, the *Genesis* of the earth, the *Genesis* of continents and oceans, and so on, as for minerals and rocks and for the scenic results of their subsequent changes. An alternative would be to use an adjective and speak of *Physical* or *Cosmic* Evolution.

(2) Transmutation.—Suggestive analogies to some processes in organic life, and it may be even for its organic evolution, may be found in the changes exhibited by radio-active substances. It is known that uranium may give rise to ionium, which may give rise to radium. Or uranium may give rise to protactinium, which produces actinium, which produces lead. There are other well-known transmutations, and there is an indirectly verified theory of the way in which the changes come about. At present these radio-active changes are all proceeding in the same direction—these chemical clocks are all running down. Thorium, radium, and actinium may each give rise to lead, or rather to a form of lead; but there does not seem to be at present any reverse or complemental process working the other way and producing heavy atoms like uranium. Our question, however, is as to the term to be used for these known

changes in the numbers and dispositions of the electrons and protons of which all kinds of matter are now believed to consist. Like changes in Organic Evolution, they occur in definite directions; like organisms, these elements give rise to others different from themselves. It must also be remembered that the change from one organic species to another may not be so qualitative as it seems at first glance; in some cases it may mean fundamentally the rise of a new protein. Moreover, it is interesting to note that a series of species, as among roses, may differ from one another in the regular increase of the number of their nuclear chromosomes, forming, for instance, a series of 14, 28, 56 chromosomes. But however inclined one may be to discover a chemical basis for specific individuality, one cannot pretend that the "pedigrees" disclosed by the radio-active changes are of the same nature as those studied by biologists; and it is suggested that the old word *Transmutation* might be conveniently earmarked for the changes by which one chemical element gives rise to another.

(3) CHEMICAL SYNTHESIS.—But there is another process of chemical change that has a suggestion of Organic Evolution and cannot be left unconsidered. We refer to the process by which the synthetic chemist builds up compounds—especially carbon-compounds—which are often of surprising novelty. Out of relatively simple materials he manufactures such subtleties as indigo, salicylic acid, and adrenalin. Often he makes things which are entire novelties, unrepresented in Nature, so he is not undeserving of the honour of being called "creative". In this connection it must be noted that according to Prof. Baly and his collaborators, it is possible to work up from carbon-dioxide and water to formaldehyde with the aid of light alone. In other words, what the living green leaf does has been mimicked artificially. Continuing the influence of light, Baly has caused the molecules of formaldehyde to unite to form simple sugars. He has also succeeded in bringing about a union of nitrates and formaldehyde in a test-tube subjected to the light of a quartz-mercury lamp. As ammonium nitrate or something similar might be brought to earth by rain following a severe thunderstorm, we see that the natural synthesis of the raw materials of the living organism is not so remote as it seemed a few years ago. There is this further interest that these novelties furnish good instances of new syntheses or "emergences". For, as in the familiar synthesis of water from hydrogen and oxygen, new properties emerge, unexpected if not unpredictable. For this kind of Becoming we suggest that the usual term "Chemical Synthesis" is altogether appropriate, with the adjectives natural and artificial prefixed if need be.

(4) ORGANIC EVOLUTION.—It seems like a gratuitous courting of confusion to mix up the biological term "Development" with the

biological term "Organic Evolution", and yet this is too common. But biologists are by this time almost unanimous in restricting the term development to the *individual Becoming* (Ontogeny), e.g. the chick from the egg, the frog from the tadpole, the moth from the chrysalis. Out of the apparent simplicity of the fertilised egg-cell there develops the obvious complexity of the fully formed organism; the latent becomes patent, the implicit manifoldness explicit, the invisible visible. In a way that we cannot image the egg-cell is an heir of the ages, with a rich equipment of initiatives that receive many different names. Development is the expression of the inheritance in appropriate nurture, and it is marked by progressive differentiation and integration. But there should be no confusion of this process of Individual Becoming with the process of Racial

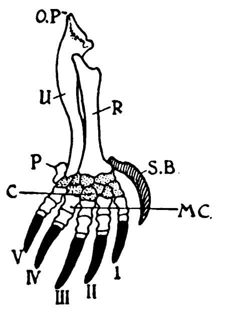


FIG. 193.

Skeleton of a Mole's Fore-arm and Hand. From a specimen. OP, olecranon process of the ulna (U); R, radius; C, carpal or wrist-bones in two rows; MC, metacarpals bearing the digits (I–V), at the ends of which there are the claws, coloured dark. P is a sesamoid bone, called pisiform. SB, special sickle-bone, which helps to make the hand a shovel.

Becoming which we call Organic Evolution. No doubt the two are correlated, for ontogeny tends in a general way to recapitulate phylogeny, as Haeckel so clearly expounded. Moreover, according to most embryologists, the intricate manœuvres that go on in the early history of the germ-cells, and continue into their maturation and fertilisation, afford opportunities for the origin of many of the new departures (variations and mutations) that form a considerable part of the raw material of organic advance. It is an interesting question whether the Becoming of the mental aspect of the organism should be called by the same name as the Becoming of the bodily aspect, yet mental ontogeny, and even mental phylogeny too, are studies in active progress, and we are becoming more and more unable to isolate the study of life from that of mind, for else biology falls towards necrology and psychology volatilises to phantomology. But at any rate there can be no doubt as to the convenience and

legitimacy—indeed necessity—of the distinction between *Individual Development* (Ontogeny) and *Racial Evolution* (Phylogeny).

Organic Evolution may be defined as a natural process of continuous racial change in some observable direction, in the course of which distinctively new individualities emerge and are established, alongside of, or in place of the originative stock. When several different parts of the organism are evolving simultaneously, it will be necessary to say "in an observable direction or in several directions".

Our knowledge of the factors operative in Organic Evolution is still very young, and obviously incomplete, but so far as is clearly seen at present, it is a process of varying and entailing, sifting and singling. There are originative factors that bring about novelties or new departures (variations and mutations). Then there is a sieve interposed by the conditions of heredity, which may be defined as the relation of genetic continuity between successive generations. For it is plain that an organic variation cannot be of direct racial importance unless it is hereditarily continued on (transmitted is a more than dubious term) as part of the specific organisation. The new departures are sifted in the struggle for existence in the widest sense, including, as Darwin clearly recognised, the endeavours the organism makes in its will to live—endeavours which are sometimes so precise that they imply a testing of a novel quality which has arisen. There is no warrant for thinking of organisms as passive pawns; they play the game, thus sharing in their own evolution, as Prof. James Ward was wont to insist. To change the metaphor, the organism plays its "hand" of hereditary cards, the shuffling of which occurred in the early life of the germ-cells, up to and including fertilisation. Besides Nature's sifting or Natural Selection there are various forms of Isolation which are ancillary to species-forming. That is to say, there are many different ways in which the range of inter-crossing may be narrowed, thus bringing about inbreeding or endogamy, which tends to fix characters. And this may alternate with a period of out-breeding or exogamy, which tends to promote variation. As we have said, the factors in Organic Evolution remain very uncertain; but what is meant is that there has been an age-long process comparable to that which is known in the production of breeds of domesticated pigeons from the wild ancestral Rock Dove, or the races of cultivated wheat from the wild wheat of Mount Hermon. In both cases there have been processes of breeding and weeding, trying and testing, singling and sifting, but while Man holds the sieve in domestication and cultivation, this comes about in Nature in the course of the struggle for existence, which rises into an endeavour after well-being. Hence, despite their likeness, the necessity of keeping Natural Selection and Artificial Selection as distinct terms, as Darwin showed. But one of the differentiating features between Organic Evolution and

Cosmic Genesis is the elimination that goes on—an elimination not of individual variants only, but of species, types, and classes. Many that share in the struggle are not represented at all in the subsequent outcome. Therefore the term *Organic Evolution* should be kept for the realm of organisms exclusively.

Or, if we prefer a single word, so often convenient, and continue the common practice of adopting scientific terms from other tongues, we might translate "Transformisme", so ordinarily used in France, as *Transformism.* Yet to this there are objections; since it, like Goethe's "Metamorphosis", which it indeed translates, is more suitable for great changes than for the small ones we have so much more commonly to do with. Hence transformism does not well suggest the modern picture of Organic Evolution, since its actual variations and mutations are, now at least, upon more moderate scale than such a word implies; at least, until we view them as a whole. Moreover, the term transformism suggests an erroneous picture of one species changing into another.

Just as there is a legitimate and promiseful chemistry and physics of the living body, though this, in the judgment of many, leaves the autonomy of biology quite secure—makes it, indeed, imperative—so there are legitimate and promiseful applications of biology to sociology. The unit in sociology is, indeed, some societary integrate, but that is composed of organisms with health and disease, urges and appetencies, fertility and mortality, and so on. Thus the biological question as to the transmissibility of individually acquired somatic modifications is of profound importance for social affairs. In short, there is a legitimate Bio-Sociology.

(5) Social Evolution.—The outworn and often misleading analogy between the animal body and the "social organism" is, or should be, abandoned; but no adequate use has yet been made of the true analogies, which are not only (1) in general, between animal societies and human societies, but also (2) more definitely, between the organic life-process of the organism in its relations, both passive and active, to its environment—and the social process in which the society is constantly interacting with its more complex environment also. (See Life-Theory, Chapter XIII). It has been recognised, however, and from the very beginning of sociology, that biological concepts or formulæ have their counterparts in the science of human societies; hence, as long as the false simplicity of "biologisms" is avoided, it is useful to inquire into social *variations*, social *heredity*, social *selection*, social *isolation*, and so on. But using similar terms for different, though analogous, processes has insidious dangers, and may land us in error, that of "biologisms", as all sufficient. Thus one too often hears social evolution spoken of as if it were only a special case of mammalian evolution; which would be illegitimate even if all mammals were of social habit, like

beavers. The differences between Human History and Organic Evolution are in kind, not merely in degree. It is not only that man is an organism of rational discourse, he is more or less aware of his own past; he "makes history", and he controls his conduct in the light of general ideas. Animals sometimes work towards a concrete personal end, with something of intelligence as distinct from instinct, but they do not give evidence of forming concepts. Man's "reason", on the other hand, is beyond mere perceptual inference or intelligence, and works with concepts, which he not only develops, but uses in his endeavour to deliberately control his actions in reference to an ideal. And the social heritage of gains registered outside the organism altogether, as is slightly anticipated in bee-hive and ant-hill, has become in man important and even dominant; and it should never be confused, as is still too common, with the germ-plasmic "natural inheritance". It is thus necessary to clarify our conception of Social Evolution proper; and this with some fullness of argument and illustration.

Organic Heredity and Social Heritage.—Everyone sees that heredity is the main biological condition indispensable for human continuance, and so for social existence; and it needs but little acquaintance either with contemporary social life or past history to see how deeply particular heredities can influence social life. The eugenists, at present among the most active of human and social biologists of practical aims, are constantly reminding us that historic and even contemporary recognition of the importance of heredity does not go far enough, without a more than corresponding appreciation of its significance for the opening future; and this not only as regards the preservation and, if possible, improvement of organic and racial breeds, but above all for social preservation, and progress too. All this the sociologist, of course, accepts and teaches; yet after the eugenists' and all other biological contributions have been accepted, and that appreciatively, he turns round upon the biologists with the proposition that where their valuable and necessary contributions end, there sociology proper begins. How so? Because the essential and characteristic task of this science is not merely to elicit these contributions towards the better understanding of societies and the conditions and needs of civilisations, but to understand societies and civilisations themselves. Hence beyond all the sociologist can learn from the "preliminary sciences", as from the first he has described them—though with due recognition of their being far more advanced and better organised than is his comparatively recent and yet more complex and difficult endeavour—he claims autonomy and distinctness for sociology, outside and beyond their respective range. How is this justified? By pointing to something beyond organic heredity altogether, the Social Heritage; that is, the cumulative

tradition of human societies, and practically of these alone. This heritage is passed on, more or less imperfectly, from generation to generation, at least during the existence of the given society; yet not by organic heredity; but by Social Filiation, to use Comte's initial term. Sociology has thus from its outset been inquiring into social heritages, as the essential characteristic of each and every known form of society, from the simplest observed by the anthropologist (and now also the earlier ones disclosed by the archæologist), to the historic civilisations which have so variously contributed to our own; while this latter is being scrutinised with ever-increasing intensiveness. Plainly and sociologically distinct from organic heredity in man, is obviously the progress of his arts, as from those of rude flints and earliest fires to our modern masteries of tools and of machines, of steam and electricity; or from floating log and hollowed tree, to the ships of to-day; and all with advances of industrial specialisation and skill, even organisation too, though that be still so obviously imperfect. Or again from herbalisms and wizardries to scientific medicine, and so on.

Manners, customs, and laws are other heritage-elements under increasing scrutiny; and so beyond these again, the moral and religious systems, the philosophies, and the sciences; and especially concerned with the continuance, the filiation of them all, are the historic languages and their literatures, and those current as well. Sociology has thus from its very outset been committed not merely to learning from the preceding sciences, each and all; but especially to the encyclopedic reinvestigation of all "the humanities", and also to all that "practical life"—industrial and economic, social and political, etc.— has shown, or can show. Hence among these there has long been manifest the broad distinction of all these elements, respectively as "temporal" and "spiritual" heritages and powers—"State and Church", for most familiar example. From this distinction there arises the classing of men in their social functionings; no longer as the breeds or races of the biologist, nor as the visuals, auditives, etc., of the psychologist, but now as the "people and chiefs", the "intellectuals and expressionals", and of whom workmen and masters, thinkers and leaders, are standard types, respectively "temporal" and "spiritual" in social terms.

SOCIAL EVOLUTION—By recent sociological writers, a man, viewed as a social unit, is no longer described as an "Individual". This term is being left to biology and its associated (and elementary) psychology, and to past economic and political thought, as illuminating their limitations. For current sociology, its unit is the "*Socius*", or Socian, i.e. the member of society, and always a social agent, whether for good or ill.

Social "Heritage" and its continuance by "Filiation", have

interesting parallelisms (as both these terms were indeed chosen to indicate) with the biologic inheritance, and its persistence through heredity. But since the anatomist has demonstrated the organic identity of our species since neolithic times, and the anthropologist also finds our breeds in antiquity, man's heredity is seen to be continuous; whereas his social heritages—his civilisations—have been in change, and are still. In briefest summary, then, Heredity is of Breed, but Heritage is of Civilisation; hence two equally distinctive sciences are required to investigate them. No doubt they are combined in society, like warp and woof; and each may change, for the better or for the worse; indeed, they are ever in interaction, each in its own way. Hence, too, their mutual suggestiveness, even to biological contributions to sociology, and vice versa. At times each has been pushed too far almost to mutual exclusion; hence many exaggerations, biomorphic and anthropomorphic respectively. These may be termed "biologisms" and "sociologisms", each in its own way illegitimate, and to be avoided, as tending to converse errors, and even to mistaken policies. In organic life, our own especially, there are hereditary diseases, though happily but few: whereas the social heritage has ever been more or less complicated with a burden of evils. Indeed, these often seem scarcely less complex than are the good elements of the heritage; and they are far slower, and as yet more difficult, of treatment than is disease; especially since they may be only too easily mistaken for true progress. In the organic continuity of life, and even in its course, biological "variations" may arise; and in the long run the better are selected towards survival; whence phylogenetic progress, and further ontogenetic perfection of the type. Similarly the social heritage exhibits no small degree of continuity, standardising the given society, and its members, towards what sociology—following and extending the term of law and government—calls Order. This conformity to tradition and type is obviously a condition of social life; and just as we find animal forms apparently fixed from a long past, so obviously are many societies. Yet comparable to organic variability, we likewise find variations on the social level. Not only the organic "sport", but the intellectual, artistic, or social "genius", may and do alike appear in man; but even these latter only count for sociology in the measure of their contributions—preferably, of course, positive—to the social life, the heritage in its movement. For the heritage-bearing society and its socians, as in organic phylogeny and ontogeny too, the vital interest is of no mere past experience, nor of mere continuance into present existence either. Above all, life looks towards the ever-opening future; and this holds for the society and its members, as it does for the species and its individuals. That abbreviated recapitulation of the organic ancestry—at least in great fundamentals, however modified—which is so familiar to the

embryologist, has little or no demonstrable natural analogue for a society and its socians as such; hence the apparently universal existence, throughout all societies and times, of what we cannot refuse to call "education", or at least "instruction"—i.e. initiation into chosen elements of the social heritage, imperfect though the choice and the initiation may be. Bird and animal parents make educative endeavours too, and not without suggestiveness. With this education, so far as it is relevant, each young socian is being better fitted for his society, and towards his social functioning in it; thus, literally, he "becomes of service", towards maintaining or advancing it. Yet since the whole universe is in movement and change, and social life most of all, there can be no mere static maintenance: and what may seem so for a time, sooner or later reveals itself as not merely arrest, but a falling out, a "getting behind the times". Mere static "order" is not enough; a range of mummies shows that to perfection: and though mechanisms work in amazingly orderly fashion, so far as they go, the true order is that of life, the co-ordination of functionings, and of these towards life more effective and abundant. So here, at any rate, biology and sociology are at one in principle, however less perfectly co-ordinated than the organism a society may be. Every living being has its developmental history, and its later adult history too, in short, its life-history, as naturalists habitually say; as indeed also for the species from origin to disappearance. But this term "history" they frankly appropriate from social records; as next was taken over from the industrial revolution, and its accompanying economic and political thought, the term "Progress". This era, we now see, was then too simply and hopefully viewed at its progressive best, and that also in opposition to evils and obstructions of the past. Naturalists, in becoming evolutionists, largely adopted the like too simple view of their organic world; and it has needed long investigation—from the extreme losses and deteriorations so common in parasites to less obvious cases—to correct the too simply optimistic notion, still so popularly associated with the word "Evolution", as somehow assuredly "progressive". Hence the now established term "Degeneration". The corresponding criticism of undue optimism on the part of societies and their members, and of this especially when "rich and increased in goods", has been a main theme of social critics, from the prophets of Israel to our own; witness Carlyle and Ruskin in our youth, or Bernard Shaw and others to-day; and also many recent American writers, from economists like Veblen to the novelists of Chicago or of "Main Street". Disraeli's biting saying, that the Anglo-Saxon world is achieving comfort but mistaking it for civilisation, was thus of full historic range.

Still, however, in social life, industrial, political and more—and especially in the rapid modern evolutionary changes of these which

their historians agree in calling revolutions—the societies and persons who are most active in these continue to feel and proclaim an optimistic assurance of "Progress", so that this still remains the popularly current meaning and spirit of the word. But disillusions, as above noted, were inevitable and are increasing; till now, in our own times of Wars and After-wars, the cautious historical thinker dare hardly affirm progress, and so feels inclined to abandon the very word, as Prof. Bury's recent Essay on Progress sums up towards. Will "History" then suffice? Only so far as we stretch it beyond its original and ordinary use and meaning, as narrative of past events, and extend it through the present into the future. So far that seems well, for a thoughtful minority at least; yet the recorded past, the passing present, and the as yet undiscerned future, cannot be included in the same term "History"—itself so much more historically established than is any other term in social science, such as "Progress", to take this conspicuous and comparatively recent example.

Moreover, to give up as a scientific term this word "Progress", because at times confused, misused, indeed too often abused, even to charlatanism, would also be losing its better use, to express advance in social evolution, and of its heritage accordingly; which is so often inspiring, and this to whole peoples, and their generous youth above all. We should thus, as the German proverb puts it, be throwing out the baby with the bath; for what could be more discouraging to the public, whom science in these days soon reaches. For a new misunderstanding, from dropping their so familiarly hopeful term, would speedily arise, even to press head-lines, thus: "Social Scientists no longer admit Progress!" To correct this might be yet more difficult than it now may be to explain for society and socian, just as the biologist does for race and individual, that "Evolution" and "Progress" may unexpectedly turn in very undesirable directions, and, in fact, give place to degeneration and regress; a change which indeed constantly needs guarding against. Let us follow the example of our prophets above-named, and so hold up the symbolic Y of Pythagoras; for here is the perpetual choice before us, progress by the broad or by the narrow way, by the difficult right-hand or the easier left?

Finally, too, the sociologist must recall that Progress is no merely popular term; but has had its best meanings and uses clearly defined, since the very foundation of his science. He thus cannot but claim that Comte's lucid exposition of "Order and Progress"—with "Order the basis, Progress the aim"—was critically reached and soundly explained; and ethically too; for his full formulation includes between its Order and Progress clauses: "Love the principle".

SUMMARY.—It is now full time for summary of this whole present

quest, of clarified nomenclature. Evolution has an all-embracing sense; but its process in the physical world, as *Inorganic Evolution*, we may describe as Genesis (aided by Transmutation, and by Chemical Synthesis). In the biological world, we have *Organic Evolution*, as Phylogeny; and in embryology for its individuals, *Development* (Ontogeny). And in sociology we study *Social Evolution*; and, must we not add, *Socian Development* for its personal participants, since the word "education" has too established limitations. And while physical and organic evolutionists habitually borrow from social science its terms "History", "Events", and "Progress", and even "Degeneration", and now use them without confusion, these cannot but also retain their older social usage, though especially must we remember that social Progress may only too readily "Degress", and even Regress. So let us try to fix on this clear antithesis as terms of social science, disputable though their applications may remain between contrasted schools.

The mathematician, ranging through space and time, finds his mastery of these in the conception of movement, and this down to "point-events"; and he extends his helpful aid to each successive science; while the logician correspondingly wields his potent dialectic throughout their entire range, with criticism and clarification of each new conception they may form; and, in the measure of his philosophic spirit, to the co-ordination of every truth they reach. These fundamental sciences have thus also their full evolutionary attitude and bearing, as the relativity doctrine has last and most fully convinced us. So too evolution is traced, and with increasing advances, in the esthetic, in the psychological, and in the ethical field; and with more and more encouraging results.

In broadest view, then, the Evolution process, despite much of what we cannot but call evils—as from cosmic catastrophes overwhelming us, to degenerations and uglinesses, to diseases, insanities and perversions, and to social deteriorations and disasters, massacres and horrors, to their recorded utmost in our own times, and all threatening, ever recurring, without end—is yet also productive, and ever manifestly pregnant, throughout all its phenomenal fields, of Progress in its best senses; and thus towards the beautiful, the true, the good. It is a wise old saying, "Every man is either an Aristotelian or a Platonist"; but the evolutionist is increasingly both. For he begins with Aristotle, indeed with far wider encyclopedic survey, and towards fuller interpretative endeavour; yet sooner or later he cannot but also discover more and more of Plato's ideals, even if he were not inspired by them from the first. For each and all of these he finds inherent on the universe, however far back his studies go. Thence, too, he sees them evolving; and why not beyond the fullest forward vision he can form?

HOLISM

Here let us refer briefly to the notable book, *Holism and Evolution* (1926), by General the Rt. Hon. J. C. Smuts. The author, as everyone knows, has led a crowded and arduous life, during which, as he tells us, his companion has been a great idea—Holism—which means the evolutionary tendency to progressive whole-making. It is interesting to find that, as an undergraduate at Cambridge, Smuts wrote a book on Walt Whitman; "a study in the evolution of personality"; and later on (1910), as a relief from heavy political labours, he wrote another, entitled, *An Inquiry into the Whole.* Neither of these books was published; but some release from affairs of State in 1924 enabled Smuts to present a preliminary statement of his long-cherished and tested doctrine of Holism. It is a serious contribution towards the upbuilding of a new constructive world-view, and very important if Smuts is right in his conviction, with which we fully agree, that in the last resort a civilisation depends on its general ideas. "If the soul of our civilisation is to be saved we shall have to find new and fuller expression for the great saving unities—the unity of reality in all its range, the unity of life in all its forms, the unity of ideas throughout human civilisation, and the unity of man's spirit with the mystery of the Cosmos in religious faith and aspiration." He thinks that the idea of Holism may be a guiding idea in the present time of transition, when "we are threatened with reaction on the one hand and with disintegration on the other. The old beacon lights are growing dimmer, and the torch of new ideas has to be kindled for our guidance". What, then, is the torch of Holism? It is the idea that "evolution is nothing but the gradual development and stratification of progressive series of wholes, stretching from the inorganic beginnings to the highest levels of spiritual creation".

Of recent years the scientific outlook has become more synoptic, trying to take account of all the orders of facts—such as matter, life, and mind. It seeks to see things whole; in other words, the analytic scientific outlook is giving place to the synthetic and philosophical. This change has been brought about by several factors, such as the unifying concept of evolution, the general idea of relativity, and the increased correlation of the sciences in investigation. Moreover, the old mechanical or billiard-ball theory of causation, that there can be no more in the effect than there was in the cause, has been recognised as partial and often irrelevant; as is particularly evident in organic evolution, where some new synthesis has so often emerged, as a qualitative advance, not a mere additive resultant. It has also become clear that each science by itself is bound, by the nature of its methods, to be partial and

abstract, fishing in the sea of reality with its own particular kind of net, and necessarily missing much that is there.

Thus there has been a compulsory retreat from an extreme mechanistic position. If, for instance, we are thoroughgoing evolutionists, then there must have been more potentialities in the original nebula than are describable in the physico-chemical terms of ordinary use. On the one hand, the structure of the atom turns out to be more organismal than used to be supposed; on the other hand, such processes as Natural Selection turn out to be less mechanical than the extreme post-Darwinians imagined. "The old fixed concepts and counters of thought are breaking down." Space and Time become Space-Time; the entire universe has a definite structure—a vibrant web of inter-relations; things, and concepts too, meet and intermingle in their surrounding "fields"; the gulf between matter and life has been much narrowed. The distinctiveness of matter, life, and mind (cosmosphere, biosphere, and sociosphere) remains; but science is getting nearer the underlying continuity.

There is a factor in matter that makes for structure, or, as some would say, for integration. Thus the atom is a microcosm, whose external properties are the expression and resultant of its internal energies and their structural grouping. In the second fundamental unit structure of the universe—namely, the cell—there is something more; there is a factor making for central regulation and co-ordination of all the parts. It is, indeed, characteristic of the organism that the parts appear to have a common plan or purpose, making for the common well-being. What is this inner integrative factor in evolution?

According to General Smuts, there is operative throughout the universe a factor which works towards the creation of progressive wholes, hence the term Holism, from the Greek *holos*, a whole. Thus a chemical compound like water is more of a whole than a mixture of hydrogen and oxygen; and a cell is more of a whole than a molecule of water; and a bird is more of a whole than a cell; higher still are minds; and highest of all is a human personality. We live in a universe of whole-making. "Holism is a process of creative synthesis; the resulting wholes are not static, but dynamic, evolutionary, creative."

Evolution is occasionally retrogressive, degenerative, disintegrative, but, on the whole, it has been progressive, advancing, integrative; and many evolutionists have laid emphasis on the successive emergence of new and higher syntheses. What, apart from terminology and lucid exposition, has General Smuts to add to this idea of evolution as characteristically integrative? It may be answered that he has deepened our appreciation of what is implied in each and every "whole", in which new aspects of reality emerge. Thus while

a living creature answers back to a stimulus, the real cause of the response is not the excitant but the whole. This transforms our concept of causality, previously too much based on billiard balls, i.e. on mechanics. Moreover, the idea of the whole leads us on to the concept of creativeness, and to the recognition of an increasing freedom as the series of wholes progresses. "We are out of the bonds of the old crude mechanical ideas, and we enter an altogether new zone of ideas and categories."

The word Holism is sometimes used by Smuts to denote a world-outlook, and sometimes to express a tendency deep in the nature of things. In this second sense Holism is the ultimate synthetic, ordering, organising, regulative tendency in the universe which accounts for all the structural groupings and syntheses in it, from the atom and the physico-chemical structures, through the cell and organisms, through mind in animals, to personality in man. Our author does not seek to explain this in terms of anything else in the scientific universe of discourse. Yet he suggests that it may be philosophically interpreted. For "the Holism in Nature is very close to us, and a real support in all our striving towards betterment. Our aspiration is its inspiration, and it is thus the inner guarantee of eventual victory in spite of all setbacks and defeats".

In all essentials, then, we cannot but welcome this synthetic philosophy; and the more since it anticipates, in general terms, many of the synthetic endeavours and interpretations we offer, from our concrete starting-point, in this book; those in bio-psychological terms especially, but many others as well. Such undesigned agreement is surely of encouraging augury towards the returning harmony of science, philosophy, and even religion, in terms of that Unity underlying the variety of Life in Evolution, which we are here seeking to express, and at so many levels, from microbe to man, and from simplest organic life-processes to their highest outcomes, and even ideals.

CHAPTER X

BIOLOGY AMONG THE SCIENCES

CLOSE beside the old biological laboratory where we are writing, a wide corridor opens into two large museum halls, one of zoology, and the other of archæology, anthropology, and history; and each is crowded with the accumulations of a succession of active workers through many years past, into a veritable embarrassment of riches, as most museums are. Our task in this book might thus here be described as an endeavour to select from what the first of these museums presents, and still more from what it suggests, as an index to and reminder of the world of life beyond its walls; and thus to express such main essentials of biology as our studies have so far yielded us, and our limits of space permit. And since any and every survey of life, pre-evolutionary or evolutionary alike, includes man, as an animal, however much the highest, we have some place for him here. Yet it next becomes attractive to ourselves, as well as to our students and visitors, to enter the adjacent museum also; with its copious further presentment of man's past and present, and its varied indications of his life and doings in interaction with his environment. Indeed as evolutionists we cannot but do this. Yet so broadly conceived and illustrated an outline survey of human and social life, as we are attempting for biology would obviously exceed our limits, and powers. Our essential task is to outline our biological world; so we are, as it were, bringing out into the public corridor, and placing on the side next the zoological museum, a choice of exhibits to indicate some of its main interests, with a few illustrative selections from the adjacent botanical and palæontological museums as well; and we are writing beside these such explanations and interpretation as we can.

Starting with simple organic forms, we have come last to man, and necessarily in his animal aspect. Yet the biologic interests we have here developed are not only morphological, palæontological and classificatory, physiological and developmental, etc., but ecological; and thus so far social, and even psychological as well. We thus feel attracted, and even prepared, indeed compelled, to enter the adjacent museum, and note what it can teach us as biologists of man's ways and doings, and thus of his simpler social ecology, and of his psychology too. We find each of our biological sub-sciences here further represented by social man, and this on a usually (though not invariably) far more comprehensive and elaborate scale than in the animal world. So next, after a little more familiarity, we

venture to suggest that the arrangement and contents of this museum will be clearer if a kindred selection of its type-exhibits be brought out to its own side of the corridor, with explanations of their essential significance.

Suppose these twofold attempts executed, and each at first made from its own side: soon there appear strikingly interesting parallelisms. Each may find the suggestions offered from the other side at first not very encouragingly received, yet later being considered, and sometimes applied; and these increasingly, as the humanists and we find we can co-ordinate our ideas, as, for instance, ours of organic evolution with theirs of progress and decline. And these agreements become of greater mutual interest, when, as naturalists, we tabulate the sub-sciences which are cultivated in biology, and next find that the very like have all been in progress in social studies, and from earlier times than have ours. In this case, the sociological workers and their students may very naturally remark that though our biological selections and interpretations have more interest and suggestiveness than they—and still more their predecessors—had realised, they are also coming to see that we and our biological predecessors have somehow learned, and even applied, a good deal more from human studies than we knew; and so can hardly have been such independent and detached observers and interpreters as we had been accustomed to think.

Leaving this and all questions of mutual indebtedness and borrowings, conscious or unconscious, for historic and biographic inquiry, the essential matter is to get to agreement as to these respective sub-sciences, biological and social respectively. For if this be attained, we can both not only better arrange the parallelism of our type-exhibits; but even condense and abstract all these anew; and as it were into a closely analogous outline panel over our respective doors (see end pages). If and when this can be done, these in turn aid, and even commit, each party towards making a clearer selection and arrangement of his type-collection, say in the corridor. Indeed must not this become increasingly suggestive, towards the arrangement of each museum, and helpful towards the teaching of its fuller significance? For since all concerned on either side are personally limited in practice to such subjects as they can productively specialise in, it is all the more necessary to have thus clearly before us also the special fields of others; and all these in their necessary and intimate harmony, and even unity. We thus come more and more to realise the harmony of biology and sociology with each other; and these not only as collaborating in their studies so much akin, as of life in evolution, but all these in an order consistent with that of the preliminary and inorganic sciences as well. In such ways we should have a sounder approach to the social questions on which biologists are ever more actively entering; as to

mention only the more obvious, as of races, of populations and eugenics, as also of public health and wellbeing.

BIOLOGY AMONG OTHER FIELDS OF STUDY.—Thanks to a good architectural adjustment, our corridor leads forward to a wide oriel window from which to look out into the wider world of life, from which our studies come and to which they must ever return. In the opposite direction, the corridor opens into the great hall of the University, in which its studies are reviewed and adjudged year by year. Here then all our synthetic endeavours have also some day to be brought together; but we are not yet ready to enter this. Let us rather descend from our corridor, with its outline of life-studies, and look over the University anew. Without entering into its range of humanistic departments, we are here first concerned to note the studies which deal with distinctive fields of biological science, not only anatomy, histology, and physiology, with their manifold applications in the school of medicine, but more especially the zoological and botanical departments, with their naturalistic and applied interests. Next, as necessary to all such biological studies, we have to profit by the physical and chemical departments; and these in their widening range, from simplest mechanics through physics and chemistry, and nowadays even to subtlest radiology. Yet increasingly necessary for comprehension of all these is the study of mathematics; with which logic, all-persuasive throughout the sciences, is being increasingly related, so that we may here think of them together. Hence the science student usually begins with mathematics, as the most clearly logical of disciplines, and thence proceeds through the schools of physics and chemistry, towards his biological training.

To bring all these studies further towards order is no easy task as yet. Here we may pursue the concrete clue, even technical method, which our bio-social corridor suggested, by making what we can of similar summaries and comparisons through the other and longer corridors we have traversed in this peregrination through their departments of knowledge. Imagine then the mathematician and logician adjusting their endeavours, as Whitehead, Russell, and others have increasingly been doing. See, too, the mathematician and physicist doing the like; and this for the main phases of the history of their subjects up to date, and with vacant wall panels for such further continuance as may be. Imagine again the physicists bringing out from their vast departments and apparatus rooms their essential summaries, and again as graphically as may be; so that from the simplest old lever diagrams to the chemist's balance and onwards, the student may rapidly visualise the doctrines of persistence of matter and conservation of energy, as Lavoisier and Dalton, Kelvin and Helmholtz respectively illuminated these; and

thence onwards again, as from the atomic formulæ of chemistry to the recent analysis and visualisation of atoms themselves, and even with the new alchemy of transmutation in progress. As all such needed summaries appear along these corridors, must we not imagine a fresh impetus, alike to the makers of them and to their students? Thus, recall how even the world's press, as yet so seldom interested in science, has expressed the wide interest created by the replacement of the old astronomic orrery by the magnificent working model of Zeiss? Again, the halls of geology and palæontology, leading up to the present distributions of life upon the globe, need in like manner to be broadly indicated, and as vividly as may be.

Passing now to the side of humanistic studies, we see these appropriately located by help of the long chart of time, from the various ages from which their heritage has come down to us; and as our historic outline grows more complete, it finds space for literature and philosophies, for customs and laws, in short, all the many aspects and products of human life. The various partial accounts of these cannot but go on advancing, and even clarifying towards comparisons, as these again towards pro-syntheses. The ideal synthesis is, of course, still far beyond us, if not indeed at infinity; yet those various steps cannot but be more or less in asymptotic progress, and are thus encouraging approximations.

We have thus, in principle, ignored no department, nor even specialism within it. Would not such an endeavour by each, towards such visualised outline and expression along their corridors, be stimulating to each and all? Would not we in these perambulations be reviving, and this even literally and concretely, the peripatetic philosophy of old? And this with the encyclopedic spirit of Aristotle, once more progressing from the scientific and naturalistic side towards the humanistic; and so in time coming to meet the idealists, who have sought to continue the spirit of Plato.

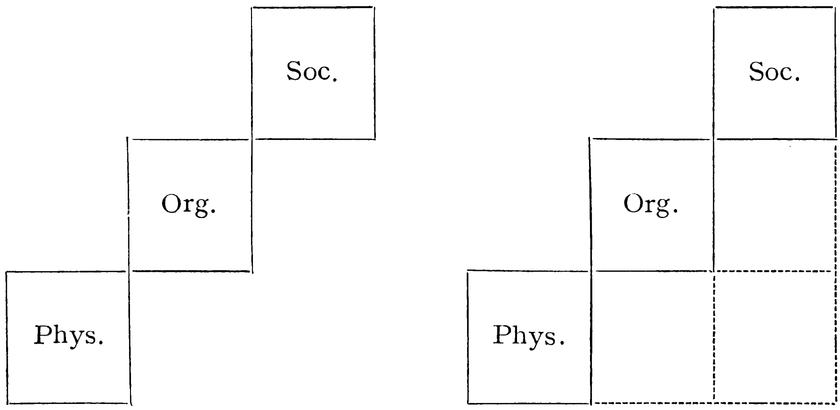
Our various imaged and storied corridors, of which each wall-space gives the outline of its adjacent field of knowledge and interpretation may thus be expressed on actual plans; and in harmony with that clear mutual presentment of the biological and anthropo-social museums from which we started. What renders possible such a correlation of scientific and humanistic studies? The common bond of essential agreement is in terms of Life and Evolution. The life-process common to these studies is that of inter-relation of organism with environment in general, and so of people and place in all human particulars. The formula already so often employed—that of organism functioning on environment (Ofe) and, of course, with the environment (more or less modified) conditioning organism anew (Efo)—is not only comprehensive throughout all organic life; it subsumes the physical world as well. The conception of humanity, in all its groupings and individuals, as acting upon their situation,

yet so far conditioned by it, no less applies throughout the whole range of human discourse. Within these parallel and yet unified combinations, our manifold departmental studies come into their right place. For astronomers and geologists, physicists and naturalists too, are alike exploring the environment of all forms of life; chemists are analysing their aspect of these environments; and all more intensively and comprehensively than ever.

In his turn the humanist points out that all our sciences have arisen in course of human life and from its activities; hence their histories begin from the simple and elemental ones of early peoples. From such beginnings in social life have developed our histories, languages, and literatures; simple arts of maintaining life arose from hunting and agricultural beginnings to knowledge of plants and animals, and the accidents and ills of life gave rise to surgery and medicine. So too our physical knowledge, with its increasing command of matter and control of energy, began with early mastery of flint and fire; and even mathematics with simple measurements, derived from the dimensions and movements of the human body. In broad outline then, the long quest of philosophy towards the organisation of knowledge is in principle simple and intelligible, not only to the simplest worker, but even to the inquiring child; and thus one feels compelled to ask how the amazing entanglements and intricacies of thought (and the arrests of it also), in which we educated adults have become involved since these beginnings, can have arisen? Has not this come about, in large measure, at least, through losing sight of this elemental and simple life-clue, amid the ramifications of each thinker's individual development, and amid the unending changes, stresses, and conflicts of this social world?

Our planning out of the fields of knowledge may thus begin, at simplest, by setting down beside our concretely outlined summary; and—as practically every separate science has done—devising a "department", as our study-shelter, in face of the phenomena to be observed and reflected on. Hence the botanic institute, between field and moor, forest and garden; and the zoological station between the animal life of the waters and land. Astronomic observatories are ever rising on hilltops for fullest view of the heavens; and the like for all possible departments: witness the archæologist and the historian in their ancient yet continuing city, the economist amid the labour and traffic of his region, the market of his town, and so on. All these institutes are already in existence, and often not a little developed; but as yet with interests more intensive than mutual: hence, towards reaching some common understanding, we need a simpler and more general plan. This now is easily outlined; even on a sheet of paper; or more vividly, as old geometers were wont to draw their figures, by tracing it upon the sand. Here, then, is such an outline, with three plain-marked squares for the main

fields of concrete observational science, with their respective interpretative endeavours; which we now call physical, biological, and social; and these may now be viewed in outline, with their relative autonomy and their legitimate specialisms; but also as in indissoluble order, thus and not otherwise. For in the physicist's square we locate our growing knowledge of the inorganic environment; in the biologist's (which must include man as animal), we gain our knowledge of organic life, in its environmental relations and its internal functionings; while in the social world we are concerned with humanity proper. In this succession and perspective, we see that the physical world so far determines the biological, and the social; and next that organic life also conditions the social life. Yet in the converse perspective, we see humanity controlling the organic world, and these their physical environment also, since not



only man, but animal and plant-life, are ever actively utilising this to their life's service.

To give this outline more completeness, and not only to scientific or philosophical students and colleagues, but to ordinary visitors—indeed to our gardeners and workmen, and even to inquiring youngsters, who thus soon understand, and that vividly, what we are trying to do—this diagram has been actually laid out, upon the terrace of our students' hall of residence. (For its outline, see end-paper, next upper cover.) Standing in the square of physics, we here appropriately look out over a quarry, and to a road-junction, with its many motors. From the biological square, that view is replaced by an old evergreen oak; now a convenient symbol of the long-enduring tree of life, with its many ramifications; while in the opposite direction runs a path through the flower and vegetable garden, and into the moor and forest. From the social square, at the corner furthest from the house-door, we may sit down by the terrace-wall, and now see the home beside us, the village hard by, and the historic university city in the distance. So in this way, concrete observation and more abstract reflection are happily

expressed together, and in perpetual reminder; even with fertile stimulus. We thus become organically, as well as abstractedly, familiar with our three main squares, here diagonally arranged; and yet more easily when conveniently labelled: here with a balance, for the physical sciences, of matter and energy; with a scarabæus for biology; and with a book for the tradition of the social sciences. These squares now need but their sides produced to furnish a complete larger square; yet thus of three more sub-divisions on either hand, so nine in all. Each of these three main fields of science has now two vacant squares in line with each of its diameters; and thus four in all for each. What meaning can we now attach to these new squares? Begin with the two lower ones adjacent to physics. The first of these brings the physicist into full contact with the square of biology. So now he can apply his balance, and other resources to a fertile study of organic life.

Thus suppose ourselves now standing in the square of Biology. The physical investigator—in the square immediately below that of biology—now explains our bodies mechanically, as a vast combination of wonderfully constructed and well-working machines; and these in terms of their energy consumed, and consequent need of replacement by appropriately chosen qualities and quantities of food. As chemical physiologist, beginning with our need of air and effect on it, he advances to subtlest chemistry of respiration and more, and rapidly recapitulates for us his whole vast knowledge of our organic life, in its physico-physiological aspect. He is thus outlining for us that education of the surgical and medical student which prepares him for repairing a fracture, for treating indigestion, and what not; yet with all this careful and fruitful survey from the side of the physical sciences, we feel he has not yet fully penetrated the organic unity of life, nor explained its self-regarding and species-maintaining activities, which remain to the biologist essentially, in their characteristic developments.

The physicist, proceeding now to his next square, that looking upwards to that of social science, sees how house and village and city are alike materially conditioned, as by fuel-supplies onwards; yet again, he has not really considered the higher characteristics of social life. The biologist takes his step nearer to this: he notes and observes the particular social conditions for which his studies have prepared him, as notably the population question, and the ways in which human groupings are all influenced by activities of self-maintaining and family-continuing, in short, by hunger and love. Each science in ascending order thus makes its contribution to the succeeding one. Our blank squares are thus becoming usefully occupied; and each by what we may follow the founder of sociology in calling a "legitimate materialism", which only become excessive, and so far "illegitimate", when these claim to replace the main

science. Each contribution is useful, indeed indispensable, as an aid to the understanding of the main science beyond it; yet is ever in danger of mistaking its square of contribution for that of the science itself. But with physical, biological and social sciences in order, we see how each of the two latter is indispensably aided by the preceding ones. So far, then, this first outline view of the observational sciences in their succession and unity.

But all along we have been tacitly using a science of a different order, not concrete but abstract; that of logic, indispensable to make our interests in our observed world scientific at all. And with this it soon becomes evident that we must also take that potent logic of measure and quantity which we call mathematics; which has almost from the first been indispensable to the astronomer and the mechanician, and next also to physicists and chemists. So now we need a fourth scientific range below our threefold concrete world. Besides his primary services to the physical sciences, the mathematician has long been making his contribution, and that of arithmetic especially, to the social world; witness his statistics, as notably of social relations in terms of money-notations; and this indeed so clearly that economists long mistook such studies for their whole science, without properly entering the social field at all. Within recent times, too, indeed within living memory, the statistical worker has successfully made contributions to the understanding of biology as biometrics; so we are compelled to assign to mathematics, at its longest range, not only a square of its own, but three contributory ones, underlying each of the other sciences. His services are thus great and even indispensable. Yet he is apt to go too far when he claims that "all science is measurement": for though the more quantitative measurement each science can get the better for it, its own problem, quality, and character remain in every case the main thing; so that the function of mathematics is fundamental, but not supreme. The mastery of the mathematician, as such, is limited to considerations of space, movement, and time, and of course number; and all observed phenomena have thus to be considered, as far as may be. The physicist has his own distinctive concepts, of matter and energy: and these are fundamental to the understanding of living beings. Yet never is the distinctive field of the biologist superseded; for nutrition and reproduction, self-maintaining and species-continuing functionings, are a long step beyond the functioning of machines; since self-adjusting, self-adapting, self-repairing, and self-co-ordinating, as no machines have ever been, nor can be conceived fully to be.

The biologist, in his turn, does great work underlying the distinctively social field, as, for instance, in elaborating his conditions for public health; and again, as eugenist, by insisting on the significance of heredity for the adequate continuance of the community,

and so far as possible even for its improvement. Yet the essentials of social science—its historic tradition and heritage of civilisation, for prime instance—remain clearly within its own field; and so have been too easily forgotten among the external contributions, statistical, physical, and organic, which are offered it from the preliminary sciences.

THE ARTS WITH THE SCIENCES.—All this becomes plainer when we now next add to our diagram of the sciences that of the corresponding outline of the activities and arts from which they had their birth. For here the order is no longer ascending, but now clearly a descending one. The social group, from its family and tribe, its region and city, not only develops its own civilisation, its heritage, both material and immaterial, as of organisation, language, and more, but it applies itself practically to the organic problem of its own maintenance, so initiating its biologic knowledge. The need of tools, fuels, and so on did much towards initiating physical knowledge; and for all this were soon needed number and measurement, the germs of mathematics. Thus though thought most readily proceeds in the ascending order of the sciences, action is plainly a descending order, in its active life, of arts: and from this side, of active life, the relatively passive world of thought has largely arisen, from experience. Nor is this merely ancient history: for every science is progressing, and more than ever, from the active experimentation as well as observation of all its workers, in their most real and intensive life.

Our classification of the sciences is thus plainly associated with a classification of the arts as well. First, social science with the conduct of society; second, biology with medicine, agriculture, and allied arts; third, physics, with the use of implements, and finally, even mathematics, with its refinement of measurement and movement, up to the relativity theory itself. Yet though our survey is thus growing more and more comprehensive, we must not forget that we are still thinking consistently in terms of life, and comprehending all arts and sciences as products of its evolution. Many attempts towards the co-ordination of the sciences and arts of life from other points of view, logical, metaphysical, etc., have thus been too largely non-vital, and pre-evolutionary.

Is this ordered and organic complex of action and thought, as arts and sciences, now complete? Not so: life has still richer products to show, and to co-ordinate with these elemental ones.

We have already noted that with the measured and often numbered thought of the mathematician, there is inseparably allied the most general, universal, and abstract of the sciences, Logic. Next, as we enter the concrete world of objective science, the sublime spectacle of the heavens, and that of land and sea as

well, at once arouse admiring wonder; and though in natural science the element of intellectual curiosity is the conspicuous factor, the "interest" of its prosecution is still a deeply emotioned urge, behind its observation and reasoning. Though this esthetic element may be intellectually forgotten, it none the less sub-consciously remains; and to intellectualise this in its turn, becomes the distinctive science of Esthetics. This close association of physics with esthetics is indeed perceptible throughout its history, and might be fully illustrated from many lives of physicists and mathematicians, as from Pythagoras to Einstein. Biology too has obviously its accompanying subjective science in Psychology, as we have in a former chapter been tracing from Amœba to Man. Next in the social field, though psychology, of course, has to be carried far further than with biology, we find distinctively developed the subjective world of Ethics.

Let us now take convenient symbol-labels for the sciences—the three dimensions and Cartesian co-ordinates of mathematics, as accompanied by the swirl of logic. The balance, for physical science, is here accompanied by the rainbow, as conspicuous for its ever-fresh esthetic appeal. The scarabæus of biology, with its close-folded wings needs accompaniment by the butterfly, as Psyche of immemorial psychology; and the book-symbol of the social heritage, with its temporal and spiritual traditions and records, is here accompanied by the ancient ethic symbol of the Tables of the Law. In this way our first page of "end-paper", as this volume's board is opened, shows the summed and co-ordinated expression of all these four dual fields of science. So if this be plain, is it not a clear case of the utility of graphics; as bringing together, and into simultaneous consciousness, what otherwise requires the long linear stream of words to express, and that less clearly?

So too for practical applications. To the great public, each and all of these eight sciences too commonly seem strange, remote, and unrelated; and though in the University we have each and all of these, they remain insufficiently co-ordinated still. For each of us has been too strictly confined to his single field; or rather, since each is indeed a whole continent of thought, to some particular field of his own within it. Whereas a synthetic diagram like this, first gradually built upon the blackboard, or on our terrace aforesaid, and this developed to comprehensive summary, and even here towards decorative panel, can as easily be remembered in after life as are the world's continents upon the map or globe.

THE INTER-RELATIONS OF THE SCIENCES.—The further development of our diagram, by the extension of each main science towards the service of its successor, is similarly indicated; and though for simplicity the symbols of logic, esthetics, and psychology, are not

continued into these spaces, they must also, of course, be similarly applied in thought. It is an old saying that every man is either an Aristotelian or a Platonist; and so far the ascending series of sciences upon the diagram broadly presents the encyclopedic outline of the former school, and as followed and developed, e.g. by Bacon, Comte, Spencer, etc. But when we recall how ethics is especially concerned with the good, psychology with the true, and esthetics with the beautiful, our diagram is now also Platonic, when viewed in that perspective, in converse order to the former.

The "materialisms" of the three initial preliminary sciences, physical, organic, and social, are shown upon this graphic chart, and they are each located strictly within its legitimate and necessary field. Their corresponding "legitimate transcendentalisms" (or say rather, higher contributions) may also be charted upon their six upper left-hand squares, yet here so far only with arrows and interrogation marks; which thus express the stimulating value of graphics, as literally "thinking machines". Towards starting these inquiries, it will be seen that the three uppermost, leftward squares afford space for outlining the way in which social life, with its practical needs, and its studies also, has expressed their demand for each of the other great sciences, from their beginnings. Next, the leftward arrow from the square of biology indicates how that has often stimulated the physical sciences (and indeed even mathematics, though to a less degree). The single arrow and square to the left of that of physics, expresses the perpetual need and stimulus of the physical sciences to arouse the mathematician to support and illuminate physics by his potent methods. For a concrete instance of the last, take Faraday's "lines of force" around his magnet, and Clerk Maxwell's masterly mathematical interpretation of these, with correlation of light with electro-magnetism accordingly. Instances of the stimulus of biology to physical and chemical sciences abound. As a simple instance, it was as a vegetable physiologist that Priestley discovered oxygen; and for later and more complex instance, the modern conceptions of ions, so important throughout chemistry, was initiated from the plant-physiological studies of Pfeffer and De Vries. And, as above said, the arrow leftwards, on the social level, expresses its early and ever-renewing demand and impulse to each and all the underlying and preliminary fields of knowledge. That the sciences are thus becoming an organised unity—and not a confused encyclopedia or historic conglomeration of books in a library, nor of "subjects" in university and school—is thus clearly manifest. And if it be asked—why introduce, into a treatise professedly biological, all these other sciences?—this diagram plainly replies. For without the physical sciences, no adequate physiology; without mathematics no biometrics; and without logic no science of any kind at all! Again, without social science, no adequate

general demand for biology, with its applications—agriculture, medicine, and public health, eugenics, and more. Indeed, without social inquiries, too little knowledge of life at all, as certainly no practical ethics, or even human psychology to speak of.

Enough, however, of this outline of the sciences; save finally to outline the position of Biology among these, and this as peculiarly central. For it needs and utilises the essential concepts of the physical sciences, and of mathematics and logic. It is plainly associated with mind in evolution; and, especially taken along with this, it affords in turn fundamental concepts indispensable to social science. It is affording standards by which to evoke and to evaluate the applications of the sciences and arts to life. Each and every science, and art also, has its contribution to the general concept of evolution; but it is in the biological field that these have been most fully applied, and can be most widely observed and interpreted, and with service to social science and conduct. Its elemental concept of Life has thus organising value and service to all the sciences and their arts, since applying this growing knowledge, guiding these advancing masteries of our cosmic environment, to the comprehension of the protean world of Life, and this increasingly discerned as by turns biopsychic and psych-organic. From earliest times there has also been a striving to understand life's evils, towards their abatement also, and now towards their prevention, or even sublimation. The progress of our science is thus towards the ever better interpretation and surer development of organic life, especially, of course, in such species as can be brought into co-operation with our own. Indeed, biologic studies and biotechnic labours aspire yet further; contributing to the life-advancing insights and activities of social progress; and thus even towards the etho-social and fully eupsychic development of humanity at its best, for which Olympians, Parnassians, and all other worthy ideals and Eutopias, of past, present, and opening future, are seen as renewing from disasters and discouragements, and as at once legitimate and re-inspiring towards the advance of life and humanity in evolution.

THE SUB-SCIENCES OF BIOLOGY.—So much for the preceding outline-charting of the sciences. But we must next consider the charting of the sub-sciences of biology itself; for to what use a mere outline of the main continents of thought, if we cannot also map out within these the fields of biology itself, so as to arrange its multifarious interests and problems as clearly? Not only biology, but each of its sub-sciences, includes the work of innumerable lifetimes broad and long; so within its vast field, here delimited from the surrounding infinitudes of other sciences, we have our minor infinities again; and these phenomenally among the most multifarious of all. Working distinctions, of course, there long have

been, as primarily that between Botany and Zoology. Each of course has its own specialisms; and more especially the latter, for (say) birds, fish, corals, microbes, insects have certainly no living multi-specialist at all adequately competent in them all; nor, indeed, as all their skilled specialists would say, has any one of these enormous groups been mastered in its manifold aspects. Yet as we compare these concrete interests, we find these alike guided by a kindred logic, from which conceptions arise common to all the multiplicities of these phenomenal forms. Hence the preceding sections of this book, which is neither a manual of zoology nor yet of botany, and still less of any single group of living beings amongst these, but a discussion of the main aspects of biological work and thought, drawing its illustrations from any or every convenient group or type. We have thus begun, as did our science, with animal stories; but these now in their more scientific form, as Ecology, which sees how life adapts itself to mastery of its environment, and not merely submits to it. From this we naturally passed to a discussion and illustration of physiological principles, seeing how the systems and organs of the body function, separately and together; and so conveniently for both fields of study, some introduction to Psychology as well.

From these studies of life's functioning, we next considered something of its forms; hence our chapters on Taxonomy and general Morphology, with some outline of comparative Anatomy, with that more minutely analytic anatomy called Histology. But taxonomy requires for its completion all the forms we can recover from the past, hence our Palæontography in outline; and anatomy needs for its understanding the fascinating inquiries of Embryography, which renders anatomy so much more intelligible. Only with this broad six-fold survey of life were we at all prepared to enter the supremely difficult discussion of its evolution, and this for groups and individuals as well; in brief, their Phylogeny and Ontogeny. So far then we have no less than eight essential sub-sciences of biology; and into these, with increasingly common consent, all its inquiries conveniently fall. And though, as already said, no man can fully master any one of these, much less all of them, we teachers have in common an intelligent interest in all these fields to share with students and readers. Yet science did not start thus equipped; thus, though something of ecology is as old as the fabulists, and something of anatomy and physiology as old as mummies and medicine, their substantial knowledge is comparatively recent. So, too, for embryology; for though touched by Aristotle, it had to wait for renewal until Harvey, and for its modern study practically until Von Baer, still a little more than a century ago. So again, despite bright speculations on the real nature of fossils, as by Leonardo, Palissy, and others, the science only really began a century ago with Cuvier. And as for evolution, though again the Greeks and

others since have speculated, its real beginnings are only with and since Buffon, while its modern discussion was mainly initiated by Lamarck, and especially developed by Darwin. So the question here arises—how can we be sure we have got all possible main sub-sciences of biology? Have we any certainty that the future may not disclose some new field or fields altogether, so far by us moderns overlooked? We may leave this as an open question for the moment; for all will agree that the main thing is, first to make sure of whatever we have already got. How best can this be done? On one side, as just indicated, this needs a study of the historic progress of biology, continued up to its present progress; so all this involves a vast literature. One not inconsiderable even from the early past; as notably from our master Aristotle, and his successors; then less important, yet not altogether negligible, up to the Renaissance, with its notable initiatives and important literature, ever increasing until the present day; so that if our reader is really determined to get fully up to date, we might provide him with references. To exhaust them for the past year, he should read (say) 2,000 pages a day during the current year, and employ such leisure as may remain to overtake the like during many previous years as well; and still be a year behind the times, since this year is doubtless producing no less! However, as neither we nor any of our colleagues have attempted any such feats of voracity, it is evident that we must have among us some organised system of indexing, and even summarising, this only too abundant literature of biology. Thanks to a great deal of co-operative labour, the bulk of this gets done: yet there is no method systematic enough to make references as easy as we all desire; nor yet certain; for the colossal disaster of losing sight of Mendel's work, between Darwin's time and our own, is not yet fully ensured against.

It is evident then that we cannot attempt any such bibliography here, nor even any general history of biology; for every such history is itself a substantial volume and filled with references to minor and departmental histories; while bibliography has many volumes every year. Hence are we not driven to seek out, as for the sciences in general, some broad outline and conspectus?—and this not only clearly defining the sub-sciences, but discerning their rationale, as well as their concrete scope, and next their respective orderly development and rational treatment. To face this enormous literature, and broadly to understand this, as well as to bring fuller human interests and understanding sympathy into each of our sub-sciences, we have to outline the main history of biology. Again therefore—there is no help for it—we must set about making graphics for these different problems, and if these can be made so as to serve as keys to these sub-sciences, as studied in nature or presented in museums, as well as keys also to their vast departmental

libraries, with clues to find whatever we really need or want, such graphs will surely be reasonably justified; and this still more if they have also served to outline the main history of the science also. Will not, in fact, such graphics serve the reader as skeleton keys, whereby he may obtain access to all biological departments of the museums and libraries, and thereafter plunder them at will? Once really appreciative of this interesting and profitable field of activity, he must reasonably give a little patience to the making of these keys, a matter which does undeniably require some time and trouble. For simplest beginning, we may readily sort out our collection of biological books and papers from among piles of others; and then again sort these into eight heaps or rows corresponding to the sub-sciences already outlined, and thus be ready to put them on our bookcase shelves accordingly. But in what order?—for each of these is necessarily at first but a minor confusion. Again, with the usual library catalogue methods, we may list all these books and papers, each on its own slip or card, since this distinctness is necessary for orderly arrangement. What principles are to determine this? Historical order first suggests itself, and so far well, for early authors especially, but obviously of no sufficient help amid the sea of contemporary literature. Biology must here supply its own classification. Its first broad distinction is that between structure and function: organisms in their life and activity and change as distinguished from the simple dissections and analyses of their forms. This principle at once aids us to put the books and papers of distinctively physiological interest on one side, say the right hand, and those concerned with morphology, and thus primarily viewed as if static and non-living, on the left. Next we can broadly distinguish, and in each of the groups on either hand, the study of single individual forms and their life, which we may now arrange for the lower half of our bookcase; and so leave its upper half for the corresponding studies of organisms viewed in their larger groupings and of their life drama. Our diagram has now its broad outline clear.

Structural		Functional	
Palæontography.	Taxonomy.	Ecology.	Phylogeny.
Embryography.	Anatomy.	Physiology.	Ontogeny.

Yet before placing the books in either top or bottom half, let us next consider what particular shelves may be needed in these to carry order a stage further. We shall come nearest to repeating the pro-

gress of our science—a good principle throughout biological development—if we first tackle the books, or more easily the catalogue cards, of which we must assume a fuller collection than that of books. How then have anatomy and physiology respectively actually developed? Broadly speaking, anatomy from the burial of the dead, as from the careful preparation of mummies; and also from early surgery from repairs of fractures onwards. Physiology on the other hand owes its origin more especially to ancient medicine, as it advanced from its earliest diagnoses and treatments. We know too little of the early precursors, summed into the traditional demigod, Esculapius; so we take our beginning from that ancient master of medical science, wisdom and virtue, who is still honoured in every medical school of the world, as its very founder and inspirer, and model, the great Hippocrates. For though a modern physician knows incomparably more in details and even principles of the working of the body than did Hippocrates, he still recognises him as a veritable model in the wholeness of his view of the patient, founded, of course, on close and thorough observation, yet with penetrative intuition as well. He thus recognises what Hippocrates called "temperament", what we oftener now call "constitution", and what the physician calls "diathesis"; and thence, with due study both of general aspect and behaviour and of particular symptoms, he reaches his forecast or prognosis, and treats accordingly. And it is worth noting here that besides this particular and general comprehension of the organism in its physiological life and as a whole, however partially disordered, Hippocrates also added a notable insight into what we now call ecology. Understanding life as interaction with environment, he wrote, besides his book on temperaments, a treatise on *Air, Water, and Places*, and he often prescribed change of these, much as modern physicians so often do. Of his many disciples in later ages we know too little, so may fear they lacked originality; for the only later great medical name of well-nigh kindred authority is that of Galen, six centuries later, and who was something of an anatomist as well. Our modern epoch begins, with so much of modern science, with the Renaissance; and in this case with the brilliant Vesalius, whose work stands to this day as our fundamental classic for anatomy; so that we may broadly regard all subsequent anatomists as his continuators, of course with more and more exactitude. Yet anatomical research has later outstanding figures; and without enumerating these, we may note that the greatest were most inspired by the desire of functional understanding as well. Hence, though we may keep their books in historic series on the side of anatomy, we may often with advantage introduce a card of reference to them on the physiological side, which the great interest of medical inquiry also aided, as of course also to this day. But disinterested inquiry was also acquiring its fascination,

so that comparative anatomy arose. Galen had dissected apes, as substitutes for human bodies; but Belon, in an immortal figure, compares the skeleton of a man with that of a bird; hence a clear beginning for comparative anatomy proper. The collection and discrimination of medicinal plants and their products has obviously been a practical necessity from earliest times, thus Aristotle's pupil Dioscorides bequeathed us his *History of Plants*. But the real ordering of plants in general and utilising the work of precursors too numerous for mention here, is that of Linnæus. His *Systema Naturæ* (1735) uses simple external characters, so contained no considerable new addition to anatomy; but the "Natural System" initiated in the later part of the century by Jussieu went further into structure, in comparison of flowers especially, so had also the merit of inspiring the great initiator of modern comparative anatomy, Cuvier. His *Règne Animal* is thus a work from which Owen and Huxley in this country, and others abroad, were direct continuators, not here to speak of their pupils and successors up to the present day.

For the working of the organs of the body, however, the epoch-making advance from the fundamental to the modern history of the subject is, of course, Harvey's immortal treatise on the circulation of the blood. He had, indeed, not a few precursors, whose particular discoveries and arguments no doubt aided and inspired him, e.g. Steno, for the valves on the veins, and Cæsalpinus with more general view, whence long controversy as to the claims and merits of the latter. Harvey's decisive position, as master of the subject and initiator of further research, has been clearly justified by historians up to the latest, Dr. Singer, whose admirable book well rewards study. And this not only for its special contents; but also for its general elucidation of so many lines of progress in science, as dependent upon bright precursors; yet these preparing and needing an editorially searching and critical mind to incorporate their contributions, and to develop from and beyond these, with originality of his own, up to a full and clear conception; so with capital importance as an initiative for future research as well. To ensure acceptance, all such work must be able to stand criticism, and to admit of verification. In Harvey's case, this was notably given by Stephen Hales, who not only corroborated his work, but extended it clearly to other animals. By his fresh, yet derived, conception of "the circulation of the sap", he became the initiator of vegetable physiology; though this has needed researches up to date, if indeed these now suffice, fully to correct and clarify his initial conception. Returning to the circulation of the blood, Harvey's most vivid continuator was Malpighi, with his ocular demonstration of the actual passage of blood from arteries to veins through the capillaries of the web of the frog's foot, observed under the microscope.

Again, though everyone has "felt the pulse", on wrist and elsewhere, from earliest physicians onwards, it is something to see this pulse too; and this anyone may observe in the regular oscillation of his suspended foot, when sitting with one knee crossed over the other. Now suppose a straw attached to the shoe, thus every movement will be more clearly manifest; and we can next even record this by drawing gently and steadily across the moving tip of the straw a long strip of smoked paper. This simple principle is but refined into the sphygmograph invented within our memory by Marey, who thus provided accurate pulse-readings and records, of interest towards a far clearer understanding and comparison of the details of heart-pulsation in health and in disease, than had been reached by feeling the pulse alone. Marey was thus a real initiator, or sub-initiator; and again was followed by later and subtler experimenters and interpreters, of whom the late Sir James Mackenzie may be cited as eminently productive, and also suggestive in his turn.

Our principle then is becoming plain, that of attaining a clear view of the progress of each and every line of biological (and indeed other scientific) research in terms of its progress and development, from early Precursors to Editor-Initiator, and thence to Continuators, at best more or less initiative in their turn. Such arrangement is thus obviously educative for us as scientific workers as well as students; and calculated to inspire all concerned towards critically reviewing that line of progress; and constructively continuing it; even to comparing and co-ordinating this with other lines of advance. Before leaving the physiology of organs, one other eminent name may be mentioned, that of Claude Bernard; and here for his best-known research, that of interpreting the essential functioning of the liver, not to speak of his widely comprehensive grasp and influence throughout physiology as a whole. Enough, however, within our present limits, if we see on our shelf for the literature of organs, its general line of development, on the anatomical side from Vesalius, and on the physiological side from Harvey onwards.

But organs need analysis, hence the significant and initiative work of the brilliant anatomist Bichat, who first clearly gave us the conception that it is not sufficient to know all the particular organs and parts of the body, but to understand these more deeply and yet more simply, e.g. the muscles as so much muscular "tissue", no matter in what particular position, attachment, and use. Similarly, beyond tracing particular nerves, we must study nervous tissue; beyond particular glands, glandular tissue; and similarly for bones, as bony tissue; and so on. For here—says Bichat, and now as physiologist—must be sought the secret of their essential functioning. This twofold advance in biological thought marks him

among the most initiative and significant contributors to general biology, thus stirred to increasing progress.

The next great advance was made in the next generation, with the help of improving microscopes. Almost two centuries before, various observers, Hooke, Grew, and Malpighi, had so far made out the building of plant structures, as showing the tiny chamber-like spaces, which they therefore called "cells". But these observations were not appreciated until the work of Schwann and Schleiden especially led to the foundation of the "Cell-theory"; i.e. the conception of plant and animal tissues, organs, and bodies, as built up of constituent units; and these not the mere cell walls of the early botanists, but of living substance, which may or may not have a distinguishable cell wall. Magnificent use was soon made of this cell-theory, with its vivid summary *omnis cellula e cellula*; as especially by Virchow, whose *Cellular Pathology* soon proved the beginning of a new and further advance in medical and even physiological thought; since henceforth clearly bringing both into correspondence, with suggestive exchange of ideas ever since. Yet the concept of the cell remained too morphological; until it was made clear by Max Schultze, after Dujardin, Purkinje, and other precursors, that the matter of fundamental importance is its living matter. Hence the term "Protoplasm"; and by and by its clear popularisation, through the English-speaking world at least, by Huxley, as "the physical basis of life", so expressing clearly its physiological significance. This latter was most fundamentally and clearly explained by Claude Bernard in terms of its material and energic changes; as at once continually building itself up, and yet breaking itself down; the preponderance of the former being expressed in growth, and in repairing the wear and tear of activity. These conceptions were next made more precise by later physiologists, as notably Hering and Gaskell; and with clear terms accordingly—metabolism for the general process of change; and anabolism and katabolism for its constructive and destructive processes respectively. With this conception we are obviously getting deeper than microscopic anatomy can follow, so here the field of biology proper meets and gives place to that of chemistry; which, as biochemistry, has ever since been making greater and greater advance, as already indicated.

Our bibliographic principle of arrangement will thus be intelligible in outline upon each and all of our paired descending shelves, for the structure and function respectively, of organism, organs, tissues, cells, and protoplasm, each and every shelf and group of investigations having its own precursors, initiators, and continuators. With this diagram clear before us, it is seen to furnish us with a *memoria technica*, not only useful for arranging such knowledge as we can acquire, but also suggestive towards further increasing it.

To make ourselves really at home in this method, it is useful actually to take a plant and an animal specimen in either hand, and thus to practise thinking of these as whole organisms, and yet also of their organs, their tissues, their cells, and their protoplasm, as in successive order of deepening analysis and understanding.

Next as an example of how such a diagram is not only a definite and orderly scheme of knowledge, but may be used as an actual thinking-machine, suggestive towards acquiring more, we may here cite our own theory of *The Evolution of Sex* (1889), which did actually thus arise, and by help of this very diagram; as by working our way upwards from the metabolism of living protoplasm and to the respective preponderance of anabolism in ova, and of katabolism in sperms, and thence following up this contrast, through organs and their functioning, to their characteristically sex-distinct individuals; and thence again through the corresponding differentiations of taxonomic groupings, and their ecology also.

An Addition to the Preceding Analysis, of Forms and Functionings.—Here, however, a further addition is useful. The preceding descending analysis, both of forms and functions, from individuals into organs, thence into tissues, and so on to cells and protoplasm, is in use by all biologists, as every manual shows. The order in which the functions and organs are described may vary, but the main animal functions are usually taken as digestion, excretion, respiration, circulation, etc., and with reproduction commonly mentioned last (or in elementary textbooks sometimes not at all, as with Huxley's otherwise excellent and long paramount Introduction). But here the botanist makes his contribution—not simply by introducing another function, that characteristic of green plants in light, as photosynthesis—but for the main distinction, so familiar to all eyes, of the plant-life as in the first place manifested in its root, stem, and leaves, as vegetative functionings and forms, and thereafter, for usually much briefer period, advancing to its reproductive life, with its flower, fruit, and seed. The forms and functionings of the individual thus fall into two distinct Systems, the vegetative and the reproductive, each paramount in its turn; so he is compelled to press this idea upon the student of animal and human life, as no less fundamental also, however less conspicuous. Our series thus in descending order once more is through individual organism to (functional and morphological) systems, vegetative and reproductive, for which the "functions" of the customary language are rather to be called sub-functions, mostly common to both, though in varied proportions.

This introduction of a fresh bookshelf, below the initial one, is important, since obvious in plant development, but manifested throughout animal and human life as well. The importance of this has of course been pointed out from many sides, as most notably

by Weismann as regards the distinctiveness of germ-cells from those of the soma (body), and by Spencer for his antithesis of individuation and reproduction. Again, starting from reproduction and sex, we urge that upon this level, of the varied correlation of vegetative and reproductive systems, we can better understand the evolution of plants, and even apply this to the origin of species in animals; as no longer simply in terms of favourable variations of germ or soma, of cells, tissues, or organs, or of the fundamental physiological (and even chemical and energic) processes which appear in all these, but as now clearest in and between these two main systems, and thence in the complete organisms which present them. Hence our insistence on sex contrasts, not simply in the individuals of diœcious forms, feminine and masculine respectively, as in a good many plants and most animals, but also frequently suggestive of the origin of distinct species, in the genera to which they belong—witness sheep and goats, cattle and Indian buffaloes, or again of divisions of larger groups—e.g. bees and wasps, moths and butterflies—all these pairs being viewed as preponderatingly feminoid and masculoid respectively; while this general contrast, of more anabolic and passive forms with those of more katabolic and active diathesis, is traceable in larger groups throughout much more of the animal kingdom.

GROUP ARRANGEMENT.—From individual form and function, as anatomy and physiology, we come to the corresponding synthetic presentment of individual forms in their larger groupings. Here the old naturalists, culminating in Buffon, were instinctively interested above all in their "natural history" ways of life, that "larger physiology" which we now call Ecology, and which has so fascinating a literature in wellnigh every language, as notably for English, from Gilbert White's *Natural History of Selborne* up to Darwin's naturalistic volumes, and many later ones. But for the more difficult task of grouping animals not by their varied ways of life, but by their essential form, Linnæus' *System of Nature* laid down his clearly observant, descriptive, and classificating technique of classification, or Taxonomy—into varieties, into species, and these into genera, orders, classes, sub-kingdoms, and kingdoms (and finally Organisata), which, despite all modifications and re-interpretations, is substantially permanent.

Group and individual aspects of form and function thus give us the four sub-sciences

	Taxonomy	Ecology	
Structural			Functional
	Anatomy	Physiology	

But past faunas and floras, often including present groups, yet with others now extinct, have increasingly come into view since Linné's day; hence Palæontography; and since then, too, we have learned to inquire into the past of the individual as Embryography. With the movement of time thus clearly introduced, we cannot be satisfied with past and present, with forms which have been, or now are: so beyond having been and being, we look into the process of becoming, and search into the rationale of life's changes in progress. In the measure in which we are beginning to comprehend these past forms of life in their persistence or their extinction, and to discern somewhat of their process of change into varieties or species, etc., of newer type, we are so far learning something of the evolution of groups. The observed development of each individual form, from ovum onwards, is similarly so far on the way of interpretation. Such studies of evolution, of groups and individuals, and utilising each and all of the six preliminary sub-sciences above specified, are thus rising from mere "graphies" to "logies" of interpretation—so that the palæontographer now not only enriches the taxonomist, and often the ecologist as well, but marshals these towards advancing that rationale of group-history which we now call Phylogeny. Similarly the embryographer aids the anatomist to fuller comprehension and safer comparison: both seek together to rationalise form-developments, by discerning more and more of the physiological processes and functional changes underlying them: thus an increasingly rational embryology, conveniently called Ontogeny.

Here then our eight sub-sciences of Biology are clear before us, and alike inviting fuller specialised inquiry, yet also rewarding wider study of their comprehensive interaction, throughout the whole sphere of life, and in its unity, as Biodrama.

This scheme now yields answer to the question asked above—Are there no more sub-sciences? The answer is in the negative—so far, of course, as the strictly biological view is kept apart from that of psychology. For here is the simple rationale which determines these sub-sciences. It will not be disputed that all life's phenomena are conditioned by the triad of space, energy, and time. Hence, arranging our studies of these in succession, we see

(1) Material Forms in Space

Synthetised as	Groups
Analysed as	Individuals

(2) Forms viewed as dead, or living—i.e. as to Energy, as

Static	Kinetic

(3) Forms of Life in Time

Past	Present	Possible

So now, superposing these three diagrams, we have exactly that of our eight sub-sciences:

And when we insert the above terms in their respective places, we have defined each and all of our eight sub-sciences as follows:

Group, Static, Past. (*Palæontography*)	Group, Static, Present. (*Taxonomy*)	Group, Kinetic, Present. (*Ecology*)	Group, Kinetic, Possible. (*Phylogeny*)
Individual, Static, Past. (*Embryography*)	Individual, Static, Present. (*Anatomy*)	Individual, Kinetic, Present. (*Physiology*)	Individual, Kinetic, Possible. (*Ontogeny*)

APPLICATION TO OTHER MAIN SCIENCES.—Note next that this eightfold scheme, first empirically developed, but here rationalised and unified in terms of space, energy, and time, cannot but apply, and that clearly, to our studies of the physical world on one side and of social life on the other. The astronomer, like the taxonomist, groups our individual planet and its satellite with others into the solar system, places our sun among the stars, and not merely by help of the constellations, as of old, but begins to

locate all within the Milky Way, and this again in relation to nebulæ beyond. Like the anatomist and physiologist, he scans moon and sun and planets to penetrate into their structure and composition and their functioning; he reads back into our immeasurable past, and forward into the future; and thus is not only a palæontographer of the cosmos, but has long been discussing its evolution as well, as from nebular hypotheses to the origins of our own earth, and of its moon. So the geologist takes up the like inquiries, with his minerals and rocks. So, too, and especially in our own day, for the physicist and chemist, with their molar and molecular studies, and their "atoms" now analysed anew; and their chemical formulæ are each a graphic morphology of form, yet also of functioning, and these often serial, indeed evolutionary, in their way. So though bio-mechanists, bio-physicists, and bio-chemists do great service to physiology, albeit with claims sometimes excessive, even to exclusiveness, Prof. Whitehead's recent insistence on the complemental need of projecting the concept of organismal life into physical processes helps to redress the balance, and to justify that unity between each group of sub-sciences above outlined as in the very nature of things, and so of our thought of them.

Criticisms of the Preceding Arrangement.—Logical, rational, and practical though the above scheme of the biological sub-sciences claims to be, it is yet open to an important criticism, a further improvement. For it follows the older main line of biological studies, which advanced earlier on the easier and more obvious static lines of anatomy and taxonomy before reaching much of physiology or even orderly ecology; while similarly palæontography and embryography have been and are preliminary and helpful to evolutionary studies proper, of group and individual, as phylogeny and ontogeny. Yet biology has thus long been open to the reproach of too much mere "necrography", and this perhaps for botany especially, though now mainly as surviving prejudice.

A long series of philosophers, each in his way as evolutionary as his times or his knowledge allowed, might here be recalled as taking the very opposite perspective; as from Heraclitus, with his πάντα ρεὶ—all things flow—to Bergson, with his *élan vital*, his *évolution creatrice*; and here, in this case clearest of all, Hegel, with his insistence on "Becoming, Being, Having Been". Thus, as evolutionists, we must reverse the order of our presentment of the eight sub-sciences, to view the evolutionary sub-sciences at the very outset, and in the order of life's own history; hence as—

$$\frac{\text{Phylogeny}}{\text{Ontogeny}} \quad \frac{\text{Ecology}}{\text{Physiology}} \rightarrow \vdots \quad \frac{\text{Taxonomy}}{\text{Anatomy}} \quad \frac{\text{Palæontology}}{\text{Embryology}}$$

This more evolutionary and dynamic presentment is now seen freed from its initial and too empiric necrography, and at length more fully bio-logic. In fact these former static fields of study may now be subsumed by the later and kinetic ones; say thus—

	Phylogeny (with Palæontography)	⇄	Ecology (with Taxonomy)
Biology	↑ ↓	Life	. . . . ↓ ↑
	Ontogeny (with Embryography)	⇄	Physiology (with Anatomy)

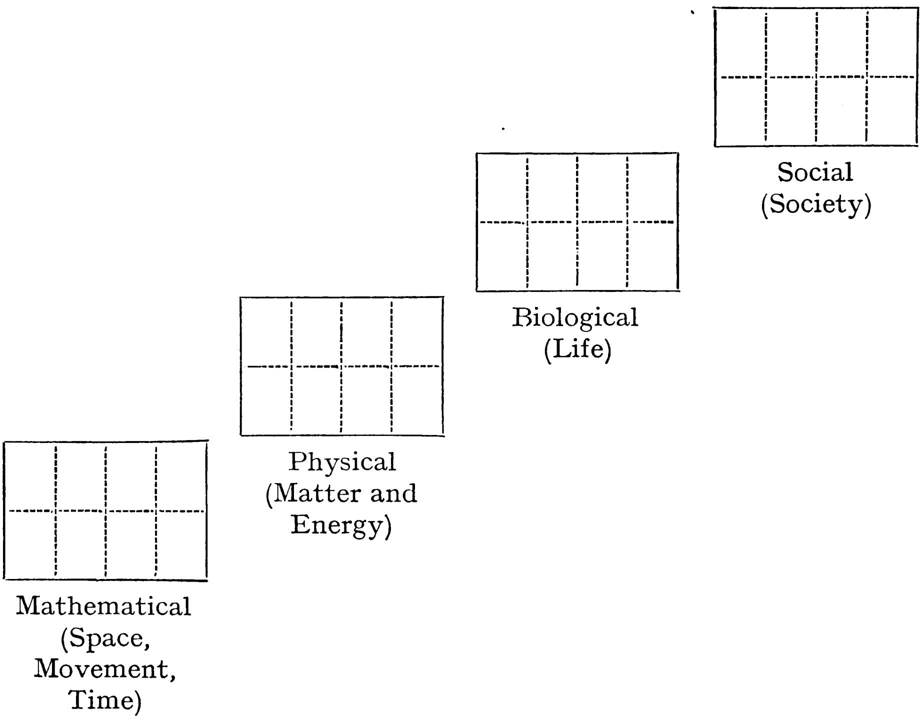
Yet these useful changes do not after all really affect the previous eightfold serial classification, but only complete our way of looking at it. For just as a world-map is shown most truly upon a sphere, so these eight sub-sciences may now best be viewed and realised as the octants of a sphere, cut by the three planes of spatial, energic, and temporal conditioning. So it is convenient and vivid actually so to divide an apple—now graphically made a veritable apple of knowledge—or thus to mark an orange, or a ball. For now we see all these three preceding arrangements of the eight sub-sciences equally plain before us, and we consider each—literally—in turn. Similarly, too, for the sphere of the physical sub-sciences, and that of the sociological ones. Indeed, even the progress of psychology and of ethics, from dawnings in simple life to most evolved humanity, may thus be presented as well.

Humanistic and social studies, as more ancient than those of the sciences, and still mostly cultivated apart from these, have of course their main divisions of labour, and each with its specialising, but all these not yet related as definite sub-sciences. Yet since they too are conditioned by space, energy, and time, their logically necessary eight main departments leap also to the eye, and as strictly parallel to those of biology. Enough here therefore to place these in diagram (see p. 1142).

We have seen how the main sciences stand in rational order and sequence; so now we see that each has the like essential divisions or sub-sciences (see p. 1142).

HARMONISATION OF SPECIALISMS, TOWARDS UNITY OF SCIENCE.—Unless the whole preceding argument be disproved, a noteworthy conclusion follows. Widely current is the pessimistic view, that the days of generalised science, and our acquaintance

"History" and "Archæology."	Ethnography.	Economics (and Politics).	Philosophy of History.
Palæontography.	*Taxonomy.*	*Ecology.*	*Phylogeny.*
Embryography.	*Anatomy.*	*Physiology.*	*Ontogeny.*
Biography.	Anthro-pography.	Economics (occupational).	Biography (critical).



Though in this presentment the physical, biological, and social sciences are seen to have each and all the same main sub-divisions, conditioned by the similar compounding of space, energy, and time, it is here worth noting that in the physical world, from stellar to atomic studies, spatial conditions are most manifest; and in the biological the functional and energetic; while in the social field, so fundamentally historic and changeful, time relations become paramount. Hence, though in all these fields of sciences we deal with space, energy, and time—say, s, e, and t—in the physical world our initial formation and clearest line of approach may be broadly summarised as S, e, t; for the biological world, E, s, t (or E, S, t): and in the social as T, e, s.

with it, have practically ended, and that the further multiplication of specialisms alone awaits us. We may smile at the extreme specialist of old when he jubilantly writes, as did Basil Valentine, in his "Triumphant Chariot of Antimony"—that "the shortness of life maketh it impossible fully to learn antimony, wherein every day something of new is discovered". But if to-day we substitute radium for antimony, we see his saying now incomparably surpassed among the manifold and magnificent labours of radiologists over the world, in their ever-increasing numbers, their fresh results, and with deep-reaching consequences. Yet there is also even deeper truth in the saying of Leibnitz—one of the widest-ranging thinkers on record, as from mathematics to history, to philosophy, and even to policy of wisest foresight—when he says—"the more a science advances, the more it concentrates into little books". For after all, though our observation of the universe is ever being immeasurably widened, as from greatest telescope to ultra-microscope, our human eye has no real difficulty in using either, and both. And so again for the geographer, whose everyday observation copes alike with the ever-advancing mapping of the great globe, with the charting and sounding of its oceans, and with the labyrinthic planning of the cities as well as that of their minutest domestic details. So, too, though even of old it could be said that "the world cannot contain the books that are written", the bibliographer is increasingly organising our command of these to-day. The like range and grasp is similarly opening in every field of thought before us; in short, a synthetic age is plainly beginning. If so, each University, at its fullest and best—besides continuing its ever-needed policy of full and free encouragement of research in all directions, and with whatever institutes are thus found to be required—must and will also complement and co-ordinate its labyrinths of departments by those of sub-syntheses for each group of specialisms; and next by that of synthesis among these, thus truly taking all knowledge for its province, and not simply by its departments; and next even for applications, towards synergy as well. Nor is this a mere sanguine prediction. Such university plannings already exist, and in East and West alike; in the East—strange as it may seem—most definitely of all as yet for the Moslem, with his deepest realisation of unity, his fullest sense of democracy as well. Yet the Western mind is of course, needed also. And this not merely by reason of its as yet incomparably more developed sciences, its more frequent training of highest powers towards varied masteries.

And in the West, woman is also coming into her own. As yet no doubt mostly but in minor ways, since within old masculine academics and politics, still unadapted to her, still less by her. But the biologist and psychologist, who increasingly discern how the life-bearing and life-tending instincts and aptitudes of her sex are

continuous with those which have steadily evolved birds and mammals alike from lower types, which were more individualistic and more combative—in short, more masculoid—can also see that her current awakening is not ending with simple equality of the sexes, as before the law, but rather beginning a new phase of social and cultural evolution. As specialists, we are as yet mostly disappointed with her; for though careful and conscientious student, often also faithful and competent assistant, she but seldom rises to leading initiative: specialist investigators like Madame Curie, however welcome, are obviously very rare. But as the housewife, fish-wife, or farmer's wife is an organiser, often better than her specialised husband or son, and so on up to queens at their highest, so there are many cases of the like in the history of culture; witness that of the *Grande Encyclopédie* itself, not to speak of the women in whom so many intellectuals have found their inspirers. Molière went to the root of the matter, for after all his pitiless criticism of *Les Femmes Savantes* and *Les Précieuses Ridicules*, he adds: "J'admets que les femmes aient des clartés de tout!" Clear ideas about everything: here is Pallas Athena, here too the "Wisdom" of Solomon; here, too, Alma Mater, as the medieval university at its best indeed recognised. The needful correlation of sympathies, calling out synergies, and their needed syntheses, is thus to be expected increasingly from woman at her best; and of course in fuller and fuller collaboration with man at his best as well. And in what studies—what centres—more naturally and appropriately than those of life and its evolution, mind and its education?

Some such architectonic outline of the living and growing Unity of Science, as is outlined above, needs increasingly to be brought and kept in view by its various workers of constructive impulse, with service to their efficiency. The scientific press—not only yearly or monthly, but even weekly—teems with fresh and good results on familiar lines of investigation; and though great advances be less common, it is ever setting forth novel and unexpected discoveries, and seminal ideas with them: so among all these, it is dangerous, sometimes even disastrous, to fall behind. Yet those least do so who have in mind the clearest general conception of the range and tasks of their science in its various fields, and with its earlier lines of quest and achievement not forgotten; and who see the relations of these with other studies, and thus with help by turns received and given. In science no less than in life, Watson's verse holds true:

> The city stands as yet
> Half-built against the sky;
> Open to every threat
> Of storms that clamour by.

Scaffolding veils its walls,
And dim dust floats and falls
As moving to and fro
Their tasks the masons ply.

As the best masons have ever been those who could best appreciate the design, the purpose and the spirit of their edifice, and this within its city's life, so with the builders of the vast university-museum-library of the sciences. This has been often so conceived throughout the ages—as from Pythagoras to Aristotle, and from the Museion of Alexandria to "Solomon's House" in the New Atlantis. The Academies and learned societies of the succeeding century arose with such great designs; and the eighteenth century encyclopedists were true pioneers of that great renewal of Germanic universities in the earlier nineteenth century which has so deeply stimulated all others. Yet the more fully architectonic classification of the sciences, best outlined by Comte, worked on by Spencer and not a few others, and here graphically inter-related, still needs re-affirmation, if we are to see even our own science steadily, and see it whole. Towards this, then, fuller and fuller classification and organisation are ever required—and all in correlation with life in its organic evolution, and in its social and cultural progress; and towards fuller and deeper, wider and more harmonious education, and even civilisation, throughout the world. For with what less comprehensive evolutionary vision and purpose can the evolutionist be inspired, and further evolved?

THE ORGANISMAL VIEW IN PHYSICAL SCIENCE.—Whitehead has ably outlined this view; yet we submit it can gain in definiteness by fuller comparisons—as with this notation of life. Despite Kant's insistence on time and space as ultimate and fundamental categories—as no doubt in ordinary thought, and in physics also till recently—are not these conceptions reached by analyses of our yet more familiar experience of movement, from which both have actually arisen for us? However, let us put down them as a triad of Space, Movement, Time: SMT. So from this we cannot but have (as with P, W, and F):

S	sM	sT
mS	M	mT
tS	tM	T

What do these squares mean, e.g. mS, as moved-Space, or movement-Space? Take a point, and move it, to generate a straight line; next move this line, to generate a plane, and again move the plane into a solid. Or, let us rotate an isosceles triangle into a vertical cone; and so on; in brief, mS is the square for thinking out our pure geometry. Next sM, spaced-Movement, is our space-measurement of distances moved, be this of growth or march, of flight or light. Now introducing Time, sT, spaced Time, is most familiarly expressed by sundial, and watch or clock-face. Next tS, timed Space, is space measured by time; as from an hour's march (the old "league"), up to *c* for light-velocity, as limit; and thus to "light-years" for stellar distances. What is mT, movement of Time? Surely Past, Present, and Possible—and this with plus or minus acceleration, in our perspectives of these. And tM, timed Movement, is familiar to us in clock-pendulum, and clock- or watch-hands, and again by stop- watch, and metronome on the piano.

All our nine squares are thus intelligible, and we submit more clearly than in the mathematician's and physicist's customary use of "space-time" as a single term, yet by which at one time they seem to mean smT, at other times sT or Ts, or what not, if not any or all inter-relations? If so, is not the above attempt towards clearing-up this idea a desirable one?

Let us try the same game in the physical level. First, with the elder physicists of our younger days, let us assume Ether as filling Space, and also put physical Energy in the square of Movement; say then Et, En, and Ti. What can we now read of their inter-relations?

Et	et-En	et-Ti
en-Et	En	en-Ti
ti-Et	ti-En	Ti

Thus en-Et, energised Ether, aids us to image Faraday's "lines of Force" around his magnet; and et-En, ethereal Energy, is familiar to us in the undulatory conception of light, and even to its spectrum as well; so Clerk Maxwell's correlation of en-Et and et-En, as of light and electro-magnetism, is more plainly rationalised for us. So ti-Et, timed-Ether, helps us to image the velocity of light, and even how this can be conceived to have its limit, *c*, in the nature of ether. What is et-Ti, ethered or etherealised Time? And

what is En-Ti, energised Time? We leave those to the ether-physicists to answer for us; but does not ti-En, timed Energy, seem the right square for the Quantum-theory?

Now leave Ether and, introducing Matter into its square (of space), what further readings arise?

M	mE	mT
eM	E	eT
tM	tE	T

First eM, energised Matter, is intelligible, since the first stone we have ever thrown, onwards to its physical refinements; and still more when we now clearly distinguish Energy as Potential or Kinetic (as indeed on the preceding Ether paragraph we should have done, but for simplicity's sake at beginning). Next mE, materialised Energy, seems at first sight much the same; but have not recent physicists taken us a step or two further? First, as in so far reviving Newton's corpuscular theory of light; again, as in interpreting the long, fixedly material atom in terms of protons and electrons, units of complemental electric energies which constitute the atoms and thus our material world? And beyond all this, yet congruent with it, note their conception of matter as no longer permanent, but as vanishing into radiant energy, and this even, as main source of the long enduring light and heat of our sun, insufficiently explained by Kelvin's and other previous simpler physical or physico-mechanical theories? Next take tM, timed Matter, a conception surely arising from the discovery of the very varied ranges of time exhibited by the degradative stages of change of Uranium and Radium, as from seconds or less to thousands of years or longer. As suggested in the preceding diagram, tE, timed Energy, includes the Quantum-theory. We can see that tM, timed Matter, may be applied (say) to the stratification of the earth's crust, and that reciprocally we may think of the strata also in terms of mT, materialised Time; since actually conserving for us the succession of past geologic times. Thus there only remains eT, energised Time, to which we find it hard to assign a simply physical conception, other than of potential or kinetic energy at or in given periods.

Finally, try now Matter, Life, and Time—MLT.

M	mL	mT
eM	L	lT
tM	tL	T

Yet since living beings have need of external energies as well as of matter, we see that we can do better by introducing both at the outset, as ME for matter and energy (a change for which the preceding graph so far prepares us) so ME, L, T.

ME	meL	meT
lME	L	lT
tME	tL	T

That Matter and Energy are essential to Life, is here re-expressed as meL, and that Life is ever incorporating them into itself, so vitalising them, is lME. That this latter is a timed process, tME is plain for all living beings, as by day and night, in nature's seasons, etc.. Next, that Life is timed, tL, is manifest for all its phases, from earliest to death. What then is lT? Life modifying Time, en-lifting it, if we may so speak. Is not this Bergson's "Durée", which we have seen to be so characteristic of living things; and also incipient in animal societies, and so developed in our own? It seems now plain that this three- to nine-fold form of graph—first devised for the clearer treatment of the interrelations of Organism with its Environment, and of Place with its People—is also applicable towards clear and simple arrangement of the main concepts of physical and even mathematical science; and one which readily may be carried further than in the above outlines; so more and more fully justifying what Mr. Whitehead so rightly urges, that organismal conceptions are needed in physical science.

CHAPTER XI

BIOLOGY OF MAN

PEDIGREE OF MAN.—Increased knowledge has confirmed Darwin's carefully established conclusion that Man emerged from a stock common to him and the divergent Anthropoid Apes. This confirmation has included a number of discoveries of fossil remains which have done something to lessen what Darwin called "the great break in the organic chain between Man and his nearest allies". This is the subject of the following paragraphs, essentially based on such well-documented treatises as Sir Arthur Keith's *Antiquity of Man* (2nd ed., 1925) and Prof. Marcellin Boule's *Fossil Men* (trans., 1923). We would point out at the start that while the opinions of experts differ as to the interpretation to be put on certain fossils, this is not a case where the strength of a chain is that of its weakest link. Even if a mistake in interpretation be made here and there, the palæontological evidence points clearly to a gradual ascent of man from an ancestry common to the Hominoid and Anthropoid stocks.

In early Eocene ages the arboreal order of monkeys, technically called Primates, was differentiated from the other mammalian orders, such as Carnivora and Insectivora. From the generalised monkey-like stock, of which few fossils are known, there diverged first of all the broad-nosed (Platyrrhine) New World monkeys, and later on the distinctly higher sharp-nosed (Catarrhine) Old World monkeys, of which latter there are some interesting fossil representatives in Egyptian deposits. In the Oligocene ages there appeared the branch of small apes (Hylobatidæ), the gibbon and the allied siamang (Hylobates), with the simpler and fossil Propliopithecus near the base of the branch. Hundreds of thousands of years afterwards, in all probability, there occurred the great divergence between the large Anthropoids and the Hominoids. Some refer this dichotomy to the Oligocene, others to the beginning of the Miocene. The large Anthropoids yielded (1) the Gorilla and Chimpanzee lines, which are near one another; (2) the Orangs, somewhat by themselves; and (3) the extinct Dryopithecus line, which apparently led to nothing.

The important *general* fact is that we must not think of a linear series, but of diverging collateral lineages, in fact as the branchings of the genealogical tree, arising at different levels. Monkeys do not lead on to apes; but there was an ancestral stem which yielded the Platyrrhine and Catarrhine monkeys on the one hand, and the

Simian or Anthropoid apes on the other. In the same way we must recognise that no living ape can be regarded as ancestral to man; the conclusion being that a generalised anthropoid line, of which we get some hint in the remains of the Miocene Pliopithecus and Dryopithecus, advanced to the great living apes, and the Hominidæ.

(1) Unsatisfactory as yet is the vagueness of the early Hominoid stem; for if the great dichotomy occurred in Oligocene or early Miocene there is a long gap—of ignorance—between that and the Upper Pliocene, or, more probably, the early Pleistocene, to which the oldest actual relics of Hominidæ are referred. These relics are the much-discussed, tantalisingly fragmentary remains of *Pithecanthropus erectus*, found in 1891 near Trinil in Java. They included a skull-cap, three teeth, and a thigh-bone, found scattered over about twenty yards, but probably belonging to one person. The skull-cap is somehat gibbon-like, indicating a brain in some respects subhuman, especially in the cerebral region. The thigh-bone is modernised, and essentially human; the teeth are distinctively human. Sir Arthur Keith speaks of this shadowy being as "human in stature, human in gait, human in all his parts, save his brain". But Boule—while admitting that the skull of Pithecanthropus "possesses characters exactly intermediate between those of a large anthropoid ape, like the chimpanzee, and of a primitive man"—is inclined to regard the type as "a large specialised form which belongs to a twig of the anthropoid branch independent of the true human branch". The general opinion—among those who have a right to have one—seems to be that the remains belonged to a creature intermediate between Anthropoid apes and "man"; and it is encouraging to recall the fact that the fossil bears a name which antedates its discovery; for Haeckel made up the word Pithec-anthropos (ape-man) to denote his then hypothetical intermediate type between apes and men. Thus is Wisdom justified of her children! We must not leave Pithecanthropus without noticing that his remains were found along with those of over twenty other mammals—*all extinct.* Their date could hardly be less than a quarter of a million years ago; and it is probable that the first emergence of Pithecanthropus was long anterior to the time of the laying down of the diluvial deposits in which the known fragments were found.

(2) Probably not much later than Pithecanthropus arose the Heidelberg man, represented by no more than a lower jaw! It is a massive, chinless, ape-like jaw, till we look at the teeth, and find them strangely human. The jaw was discovered by Schoetensack in 1908, in river valley sands 79 feet below the surface, and after about twenty years of searching; and in the same deposits were remains of pre-glacial mammals, such as mammoth and woolly rhinoceros. The date was probably First Interglacial, perhaps a

quarter of a million years ago, perhaps more. Along with the jaw were found big "eoliths",—flints with little or dubious trace of having been worked; and if Heidelberg man used them habitually, he must have been a strong fellow. Some have called him *Palæanthropus heidelbergensis*; others have placed him in the same genus as Pithecanthropus; and others have ranked him as Homo. The

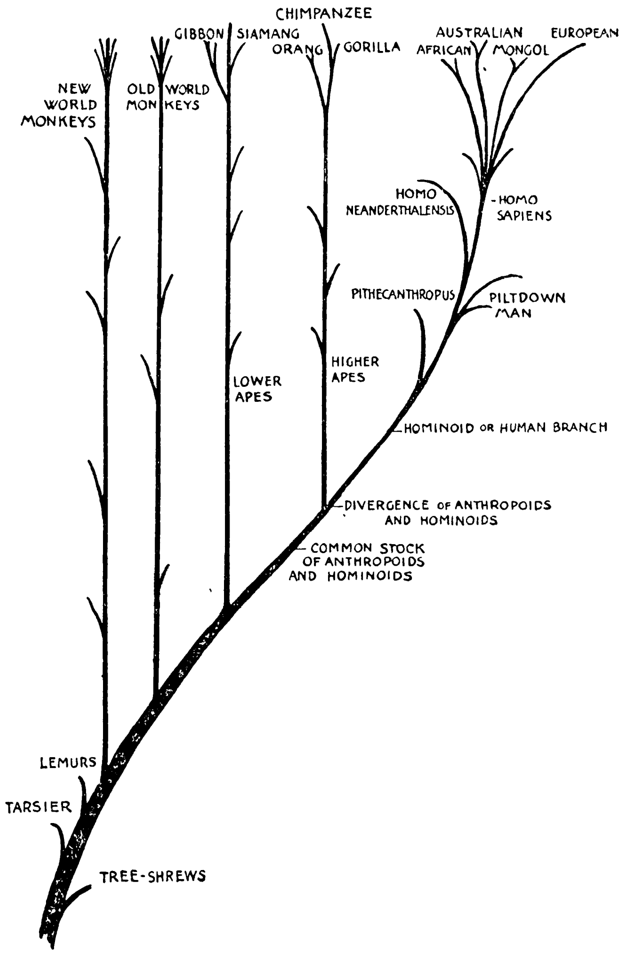


FIG. 194.
Diagram of Ancestry of Monkeys, Apes, and Man. After Keith.

outstanding fact is that the lower jaw is strikingly intermediate between the ape and the man. As Boule says, it is "a palæontological relic representing, in an almost ideal way, a form intermediate between the structure of an ape and of a human being". The jaw is an ape's, the teeth those of a man. Keith regards the Heidelberg man as on the way to the Neanderthal type of Homo.

(3) The third important relic is the skull of Piltdown Man (*Eoanthropus dawsoni*), discovered by Dawson in 1911–12 in a gravel

bed in the Sussex Weald. Fragments of a second specimen were subsequently found about two miles away. The remains were associated with those of Mastodon and Woolly Rhinoceros, and with crude eoliths. The gravels are referred by some to the Second Interglacial time, in the Lower Pleistocene; but Keith regards the Eoanthropus as Pliocene. The skull, pieced together from fragments, is very thick-walled, with a rather steep, yet ape-like, forehead, without prominent brow-ridges, and with a primitive simian-like brain-case. But the lower jaw is surprising, a veritable bone of contention; for the chinless front part and the canine tooth must be called simian, while the posterior part and the molar teeth are human. Thus the outstanding fact is the mixture of ape-like and man-like characters. Perhaps it should be noted here that there are as yet no certain remains of Anthropoid Apes in Britain. The Piltdown lower jaw is certainly not that of a modern man; but it

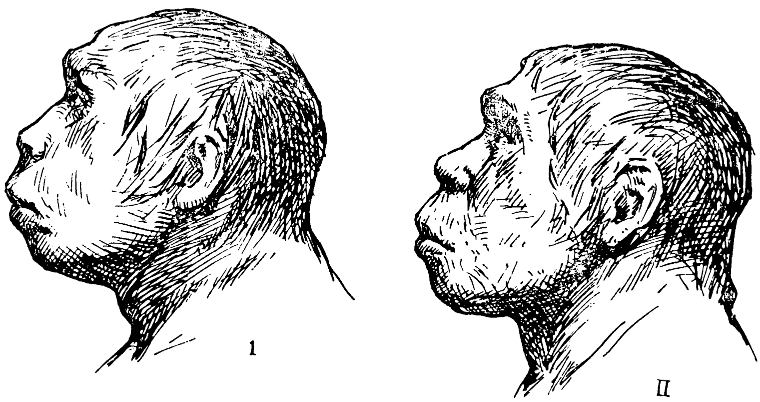


FIG. 195.
Reconstruction of the Head of Pithecanthropus (I) and of Neanderthal Man (II). After MacGregor.

cannot be claimed that there is unanimity of interpretation, for some still say that the jaw belonged to a chimpanzee, while Keith on the other hand speaks of Eoanthropus as "the earliest Englishman we know of as yet". A palæontographical Sherlock Holmes declares that the remains of Eoanthropus are those of a woman, and that she was drowned!

A great point is that the brain of Eoanthropus was equal to that of modern man—a very remarkable fact, for there seems no doubt as to simian features in teeth and mandible. Keith, as above cited, regards the Piltdown skull as that not of a tentative man like Pithecanthropus, but of a species of Homo, like the Neanderthal man and the Rhodesian man. Sir A. Smith Woodward, who has been equally zealous in the study of these ancient relics, regards the Piltdown type as near the common ancestor from which the Neanderthal man and modern man have been derived. The data are still too sparse to allow of precise pronouncement.

(4) The fourth step brings us to Neanderthal Man, *Homo neanderthalensis*, so-called from a skull-cap and some long bones dug up in 1856 in a grotto in the Neanderthal valley, through which flows the Düssel, a tributary of the Rhine. Huxley regarded the depressed skull-cap with its prominent eyebrow ridges as that of a primitive man of our own species, and others, including Virchow, interpreted the primitiveness as an expression of disease or imbecility. Before that, however, in 1848 there was found the somewhat similar Gibraltar skull; and the interest of anthropologists was intensified by discovery after discovery of other widely scattered remains of the same Neanderthal type,—such as the lower jaw of La Naulette, the fossil men of Spy, in Belgium, a skeleton from La Chapelle-aux-Saints in the Corrèze district, a fine skull from La Quina in Charente, and the like from other countries. Well-preserved parts of at least fifteen individuals of the Neanderthal race have now been studied.

Neanderthal Man lived along with the Mammoth Fauna in a period more remote than the Mid-Pleistocene, and he lasted till after the emergence of our own species, *Homo sapiens*. He was a stocky short-legged man, about 5 feet 3 inches in height, but slouching forwards. He has been described as "a clumsy, shuffling, loose-jointed being of great muscular power". The skull is very large, above our average; the vault is low, the hinder part protuberant and vertically compressed; the eyebrow ridges are very prominent with a markedly receding forehead; the face was thrust forward like an ape's; the lower jaw is strong and still chinless; the teeth indicate a coarse vegetarian diet, with small game for relish. The brain was large, but presented, as Boule sums up, "numerous primitive or simian characters, especially in the relatively great reduction of the frontal lobes and the general pattern of the convolutions".

Sir Arthur Keith tells us that though Neanderthal Man showed "simian characters swarming in the details of his structure", he was neither primitive nor anthropoid. He was a man, yet an unsuccessful species of Homo, and not ancestral to us. That some "neanderthaloid" skulls occur in humanity to-day, showing now this, now that, feature of the Neanderthal type, probably means a reversionary appearance of characters of the old-fashioned Homo stock, from which *H. neanderthalensis* and *R. sapiens* alike arose. But it cannot, of course, be affirmed that there were never crosses between the two species during the time that they lived contemporaneously.

One wishes that it were possible to penetrate nearer Neanderthal Man as a person; but the most intimate studies of the skulls and the brain-casts do not carry us very far. His jaw indicates him as probably a very silent man; he was a native of the North and chilled by its severities. He knew how to light a fire in his cave, and he made stone implements with a style of his own. But little more can be safely said of this isolated type, who seems "the terminal bloom of

a twig, now withered and dead, of the human branch". His place was taken by unmistakably finer post-glacial men, of the reindeer age, to whom we shall presently turn.

(5) In 1921, Mr. W. E. Barren, a mining engineer, making his round in the great Broken Hill Cave in Northern Rhodesia, came across a black labourer thrusting his pick among a medley of animal bones exposed by a successful blasting. With a keen eye for the unusual, he intervened just in time to save the skull of Rhodesian man—"the most complete and important document that has yet lain on the anthropologist's table". It was much in the same way that Mr. Dawson—a scholarly lawyer—saved the Piltdown skull from forming part of road-mending material—the probable end of not a few of our ancient forerunners. At Broken Hill, however, remains of at least two skeletons were preserved for science. The remains were not fossilised; the teeth are unique in showing caries, a disease never before observed in a pre-historic skull. The associated bones in the cave were those of living species; yet their date is Early Pleistocene, probably less than one hundred and twenty-five thousand years ago.

What is it that makes the remains of Rhodesian man so interesting? It is that his skull suggests the common ancestor of the Neanderthal and the modern types. His body skeleton is modern, but "in his skull he combines the cranial feature of the Australian aboriginal and of the La Chapelle man". Sir Arthur Keith, who has studied Rhodesian man with rare skill, says: "His just place seems to be in the modern stem, soon after this stem had broken away from the Neanderthal line. It is just because his origin lies so close to that of Neanderthal man that Rhodesian man has so much of this type still in him. He stands to the modern type in almost the same ancestral relationship as Heidelberg man does to Neanderthal man."

The general fact that stands out is that in early Pleistocene times, probably not much more than 125,000 years ago, England, Germany, and Rhodesia alike had primitive *men*, of a definitely human type, —even in many ways modern. But the links between the Heidelberg man, the Piltdown man, and the Rhodesian man on the one hand and ourselves and the Cro-Magnons (apparently of finer build and brain than ourselves!) on the other, are still awanting. Here is another link still missing; the first being between the origin of the humanoid stem and Pithecanthropus, or whatever other *tentative man* may have preceded him. We cannot leave Rhodesian man without noticing that besides the dental caries already mentioned, he had dental abscesses and considerable rheumatism. His skull, like the later Boskop skull, shows ear-lesions "of an obscure and puzzling nature".

Beyond these Rhodesian remains it is not necessary for our

present purpose to continue the story; but careful search has lost none of its zest, and, as the recent "man of Taungs" shows, is certainly not failing of its reward. The ascent of man is thus undoubtedly becoming more and more clearly deciphered.

A general summary may be useful (and this in ascending order, as a geological succession).

C.	POST-GLACIAL	RHODESIAN, GRIMALDI, CRO-MAGNON TYPES.
	↑	
B.	PLEISTOCENE (GLACIAL and INTERGLACIAL TIMES)	NEANDERTHAL MAN (4th GLACIAL PERIOD). PILTDOWN MAN. HEIDELBERG MAN.
	↑	
A.	TERTIARY	PITHECANTHROPUS. HOMINOIDS DIVERGE FROM ANTHROPOIDS. DIVERGENCE OF GIBBONS.
	EOCENE	DIVERGENCE OF MONKEYS. ORIGIN OF PRIMATES.

A. TERTIARY.—Two general impressions are strong when we think of the ascent of man; and the first is that of wide diffusion at a very early date. This has been well expressed by Keith: "In reality the Garden of Eden was world wide. Even England was part of it —apparently an important part. So were the continent of Europe and the ancient lands of Egypt and Mesopotamia. Our search shows that it extended to the most distant lands of Africa, Australia, Asia, and America. Nor was the drama of the Garden enacted in a single morning; it has been going on for a million of years, and is still unfinished. There have been many scenes, and we can see no sign of the curtain being rung down on the last of them. The drama of man's evolution was not staged in a favoured meadow for a single performance; it is still proceeding in our slums, country cottages, and palaces, just as it did in the days when man's only roof was the wide dome of the sky."

The second great impression is one that we receive in other fields of organic evolution, the impression of branching stairways, or complex inflorescence, and all with a sifting-out process. Millions of years ago the Primate stem sent out its first tentative branches as the monkey tribes. Some of these have been eliminated, many persist to this day—on the whole a joyous crew. But after giving off the New and the Old World monkeys, the main stem grew on. It gave off the lower Anthropoid Apes, represented by the gibbon and siamang of to-day; it next yielded the branch of the higher Anthropoid Apes, and the branch of Hominoids. From this latter, without haste, and sometimes leading to nothing, more branches were given off—those of the "tentative men"; Pithecanthropus the Erect in Java and Eoanthropus on the Sussex Weald. At last came

Homo; but even among his different species there was the like variation and sifting; for several, like the Neanderthal men, who shared in the struggle, failed to enter into the promises. Our general impression of this long and still very imperfect history must thus not be crudely simplified, as of "man sprung from a monkey", but rather of man as the outcome of ages of travail, of tentatives and their testings. Can we wonder that the philosophically minded not only see man in the light of evolution, but are inclined to view Organic Evolution in the light of Man.

WHERE MAN EMERGED.—This is not as yet a very pressing question, for many more data must be accumulated before any secure answer is possible. It is interesting, however, to notice that Prof. W. K. Gregory, a leading American anthropologist, decides in favour of Asia as man's place of origin. His statement of the case confirms the prediction made in 1900 by Prof. Osborn, the distinguished palæontologist of the New York Museum, that Northern Asia would turn out to be the palæontological Garden of Eden; for this has been strikingly substantiated by the main discoveries of the subsequent generation. For though Europe can show an early approximation to a Hominid in the Pliocene Primate *Dryopithecus rhenanus*, and such eloquently primitive Hominid remains as those of Piltdown and Heidelberg, and though the Lower Oligocene of Egypt has also its representatives of the man-anthropoid series, there seems yet more to be said for locating Eden in Central Asia. Perhaps Pithecanthropus in Java and the owners of the Wadjak and Australian skulls were peripheral offshoots from the Asiatic centre; and the Nebraskan tooth may also represent such a migrant from Central Asia. Speaking of teeth, we must allow some importance to the 1921 discovery of two human teeth in a cave at Chou Kou Tien, south-west of Pekin, for the age indicated is Upper Pliocene or Lower Pleistocene. Thus geological, palæontological, and anthropological arguments support the conclusion that man emerged in Central Asia, which was probably in process of gradual uplift at the time. Man represents such a new departure that the hypothesis of several Edens for his emergence seems very unlikely.

FACTORS IN MAN'S EVOLUTION.—The stock from which Hominids diverged was doubtless for a long time arboreal, and this apprenticeship had many consequences, well worked out by R. Anthony and by F. Wood Jones. The hand was emancipated from being an organ of support, and remained generalised, fit for anything, yet for grasping especially. Through the evolution of a free hand, able to lift the food to the mouth, it became possible to dispense with protrusive lips and gripping teeth. Thus the snout region began to recede, and there was a correlated increase of the

cranial cavity and a shunting forward of the eyes. Another arboreal acquisition was a greatly increased power of turning the head from side to side, locating sounds and scrutinising sights. Touch was largely separated off from nose and snout, and concentrated in the hand, which came to corroborate the other sense-organs increasingly. It was also able to feel over most of the body. There was a deep change in the balance of the body on the legs, in the backbone, and in the chest. Very important was a decrease in the olfactory region of the brain, and an increase in the region where sensory tidings from hand and eye and ear stream in—a region, moreover, towards which the originative seats of the motor impulses tend to become approximated. In short, the arboreal apprenticeship with a free hand favoured the evolution of the "neopallium" of the brain.

THE VISUALISING TREND.—Certainly one of the most epoch-making of evolutionary trends was that which led among mammals to the increased survival value of vision; for one of the most striking of anatomical diagrams ever published is that which Prof. Elliot Smith gives of four brains, which illustrate the evolution of the visual area in our own. The first is that of a terrestrial Jumping Shrew (Macroscelides), where the visual area of the cerebrum is small, and the olfactory area large. The second is the brain of a Tree Shrew (Tupaia), a vivacious arboreal Insectivore with very agile movements. "The olfactory area is reduced; and the whole neopallium undergoes an even more pronounced change corresponding to a relatively enormous enhancement of the importance of vision, hearing, touch, and skilled movement for an animal living in the branches of trees." (*The Evolution of Man*, 1924, p. 142.) It may be explained that the neopallium is a receptive, recording, unifying area of the cerebral cortex which becomes large in the higher mammals. It includes various territories which receive stimuli from all the sense-organs, and is also the seat of associative memory; and it would even seem of unifying consciousness. The areas it includes are visual, tactile, motor, acoustic, and prefrontal —the last being concerned with precise adjustments of the eyes (focussing for stereoscopic vision), and with skilled manipulative movements. Whereas the Jumping Shrew's behaviour is dominated by smell, that of the Tree Shrew (in the same family!) is dominated by vision; and the advance is to be correlated, in part at least, with the *arboreal* mode of life.

The third brain is that of the Spectral Tarsier (Tarsius), which is generally regarded as an old-fashioned type among the primitive monkeyish animals (Prosimiæ), below the level of genuine monkeys, and more nearly related to the "Half-Monkeys" or Lemuroidea. "The visual territory has become very extensive and the olfactory territory still further reduced in size; and this corresponds in behaviour to the definite usurpation, by vision, of the dominant

influence formerly (even in the Lemuroidea) exercised by smell." (*Ibid.*, p. 143.) The snout is reduced in the fascinating Spectral Tarsier so that the eyes come to the front of the face and look forward. But although Tarsius has binocular vision, it is not yet capable of appreciating stereoscopic effects. Elliot Smith thinks that the creature feels the need of being able to adjust the two eyes in close co-ordination, for it moves its head about on its vertebral column through an extraordinarily wide range, almost to 180° when looking backward. "It moves its head much as a cat does, and so roughly achieves its purpose of bringing the two eyes at the same distance from the object."

No small part and factor of the progressive evolution of living beings has gone in the varied acquirement of the art of seeing; and man has grounds for congratulating himself that he seems on the whole to have got farthest. But in what different measure! As our languages show, the Japanese have here gone far beyond us Westerns in their colour-observation; but within all people this range of development varies greatly: recall the story of Turner, who when told by the philistine that he had "never seen such colour in Nature"—replied, "But don't you wish you could?" And much as muscle and nerve are trained to finer and more subtle skill, so are the naturalist's and the artist's eyes in their different ways—and so too the thinker's and the poet's, as they survey with understanding, feeling, and inward imagery as well. What better training, then, for that ontogeny of the individual and race—from Protozoon to Psychozoon—Life's main evolution—than the continuing of this long evolutionary progress of the art of seeing? Is not this a main line for the Education of ourselves and others?

Referring for details to a recent discussion in Thomson's *What is Man?* (1924), we must be content here with resuming what we dimly discern as probable factors in Man's emergence. He belonged to a clever social Hominid stock arising from ancestors common to them and to the Anthropoid Apes; he diverged at a time when several other types of mammals were experiencing great increase of brain, and to this there may have been some environmental, e.g. climatic, stimulus; he was probably an expression of successive cerebral mutations, especially in the anterior cortex of the fore-brain; this enhanced brain-development may have been correlated with the prolonged ante-natal life; a prolongation of infancy and of the play period would favour educability of mind, as contrasted with early fixation; the prolonged infancy would also favour the development of gentleness in the individual and its evolution in the race; in a social stock the improving capacity for speech, and its gradual rise into language, would certainly have great survival value; consequent on continental elevation and an associated increase in aridity, there would be a shrinkage of the forests, perhaps

in Central Asia; and the descent of Hominids from the trees was probably critical in separating off tentative men from their collaterals who remained elsewhere arboreal and relatively unprogressive; it was facing the difficulties of life on terra firma that was crucial in the emergence of Man. Let us suppose the emergence to have occurred and turn to the problem of *Societies.*

THE BEGINNINGS OF SOCIETY

There is an old saying, "The proper study of mankind is man", but it would be just as true to say: "The proper study of man is mankind", if we mean by mankind all the human societies. For the highest outcome of mundane evolution as yet reached is a human society, imperfect as all of them are. How did human societies arise?

To begin with, let us return for a little to *animal* societies, such as are illustrated by ant-hills and bee-hives, beaver-villages and packs of wolves. An assemblage of many animals of the same kind does not make a society, for a rabbit warren does not deserve that name, nor the multitude of mites in the huge cavern of an old cheese. The distinctive feature of a society, as we saw, is that the individuals can act together as a unity, combining their efforts in defence, or in attack, or in work, or in some common enterprise. A society implies some degree of corporate life, when the members act coherently and harmoniously as a unit,—when the whole is more than the sum of its parts! Thus the Amazon ants may combine in a slave-raid, or the beavers may combine to dig a canal through a large island in the middle of a river. We saw that there are many different grades of animal sociality; thus the rooks are much more socialised than the parrots, gregarious as these often are. There is much more concerted action in a pack of wolves than in a herd of wild horses. But whether the social note is loud or faint, if it is there at all it implies some self-subordination to the interests of the community. The contrast is with the solitary, self-contained, independent, each-for-himself type of animal, which may be admirably suited for certain modes of life, and also most admirable in parental care and in monogamy. The contrast between a communal or social regime and an individualist or solitary mode of life is not primarily a contrast in morals; it is a contrast in ways of getting a living and in keeping a firm foothold in the struggle for existence.

Another general feature of the social mode of life, when it gets beyond mere gregariousness, is some alleviation of the *individual* struggle for existence. In diverse degrees the society serves as a shield to the individual. This means that certain types of individual that could not survive alone, may survive under the society's shield.

Among the honey-ants of Texas there are individuals which are utilised as honey-pots, but that would be impossible except in a society! Among the White Ants or termites the big-jawed soldiers cannot gnaw wood as the workers do, so they are fed in return for their more or less military services. The drone-bees in a hive, though very energetic in flying about, have lost the habit of foraging, and get their food as members of the society or big family. The difference between a society and a big family is one of degree.

Some animal societies are *mainly* on an intelligent basis, as among monkeys, horses, cattle, elephants, beavers, and rooks, while others are *mainly* on an instinctive basis, as among ants, bees, wasps, and termites. But the contrast must not be pressed too hard, for beavers are sometimes children of instinct, and bees show occasional flashes of intelligence. Human societies are partly instinctive, mainly intelligent, and occasionally rational.

Perhaps we shall better understand the beginnings of human societies if we again try to focus the advantages of social life among animals. (1) Many small animals, such as ants, insignificant in themselves, afford good illustrations of the adage that union is strength. (2) What an individual ant or beaver could not accomplish may be achieved by concerted action, as when ants combine to bring a large victim to the nest, or when beavers unite in cutting a canal. (3) Energy may be economised in a community, especially when there is division of labour, as is so frequent among ants and termites. But this division of labour becomes extreme when the reproduction is mainly restricted to certain individuals, notably the queens and drones of the bee-hive and the ant-hill. (4) We cannot but think that it must have meant much in the evolution of an animal society when there was something in the way of *permanent products*, such as communal shelter, or store, or camp. An ant-hill, a bee-hive, a termitary, a beaver's pond, must be regarded as the beginning of the social heritage which has meant so much in man's case. (5) Finally, there must be some degree of kin-sympathy in every animal society—a "social atmosphere" in which the mental and moral qualities have more chance to express themselves than in the solitary mode of life. This would be most marked in the case of societies on an intelligent basis, for instinctive societies are apt to become too stereotyped. Communities on an intelligent basis are likely to foster the growth of wits and kindly feeling, as well as the anticipations of language and art.

Why are there not more instances of social animals? It probably requires a considerable degree of kin-sympathy and brain-intricacy. Mites could not form a society. There must also be a power of rapid multiplication, for a small society is almost contradiction in terms. Moreover there are some ways of living that preclude concerted action, as in most forms of hunting and fishing. There are only two

or three instances of sociality among spiders. These and other reasons help us to understand why the list of social animals is not longer. The formation of a society makes certain demands on its members,—above all some degree of self-subordination; and these demands cannot always be met. Successful as social life is, it is on the whole for the elect.

Perhaps we shall be helped to understand social life in mankind if we linger just a little longer over social activities among animals. How do these manifest themselves? There may be concerted action or communal enterprise; thus wasps unite against an intruder, wild cattle against the menacing Carnivore, rooks against a hawk. Or the union may be aggressive, as when the wolves in a pack unite against a deer, or weasels against a dog. Again there may be co-operation in food-getting, as when pelicans, wading in a half-circle, close in upon fishes; or combined action in making a shelter or a store, as in the termitary and the bee-hive.

But the social activities of animals are sometimes quaintly subtle. Thus among some of the slave-keeping ants, the slaves may assist in capturing others like themselves. Many migratory birds fly in wedge-shaped formation, which lessens the physical exertion and devolves the responsibility of guidance on a leader, who can be changed when he or she gets tired. Corporate nesting is illustrated by Republican Birds that make a huge composite erection almost smothering a tree, and there are some social features in the gregarious nesting of rooks. Social activities also include the "wars" of some species of ants, the ploys and plays of others, the drilling manœuvres of the penguins and their games, the choruses of some joyous birds, and the "community singing" of the Howling Monkeys.

Another line of social activity is the evolution of means of communication, by sound-signals in particular. The first use of the voice was as a sex-call, and this use remains prominent in many vocal animals, such as the croaking frogs. A second phase in the evolution of the voice is represented by those animals in which the young one calls to its parents—the unhatched crocodile pipes from within the egg-shell—or the parents call to the young ones, as when the partridges utter the danger-cry that makes their offspring squat and lie still. Then the sounds became kin-signals, which sometimes save a difficult situation. Thus an isolated monkey attacked by an eagle may summon its kindred and entirely alter the crisis. Gradually there came to be "words", by which we mean sounds associated with particular provocations, feelings, desires, or even objects. Rooks, dogs, monkeys, and many other brainy creatures have many "words", though they never attain to making a sentence. There is no true language until socially imitated sounds are used to express a judgment, and even chimpanzees, which have a large vocabulary, never do that. Man has a monopoly of language, though many

animals have speech and words. But our present point is that a society favours the development of means of communication. These need not be vocal, for bees get news from one another by smell; and in many mammals there are gestures as well as sounds. When two ants stroke antennæ there seems to be a mingling of touch-tidings and smell-tidings.

Of great interest in the social life of animals is the gradual appearance of customs and conventions, what might be called "folk-ways". These are based partly on the engrained promptings which have become part of the racial inheritance, partly on the apprenticeship that the animal may have to serve (as in worker-bees) to the traditional routine, and partly, no doubt, to the established division of labour and to the presence of permanent products, such as the termitary of the white ants with its intricate internal architecture. Why does an ant seem forced to behave in such and such a way? In trying to answer, we may perhaps distinguish an internal hereditary compulsion, which prompts, for instance, the feeding of the hungry, and an external or environmental compulsion imposed by the nature of the home, the particular form of the quest for food, and the established framework of the society, as expressed, for instance, in the division of labour. Thus, as we have mentioned already, the soldier white-ants have to be fed by the workers, for they cannot feed themselves.

In societies of fine-brained animals there may be the beginning of something like social compulsion, something pointing onwards to public opinion in mankind. Perhaps, to take a familiar instance, there is some expression of this in the cold-shouldering of the drones in a bee-hive. It seems to grow in intensity, and it may end in their massacre towards the end of summer, though that is often rendered unnecessary by a gradual reduction in numbers.

But let us turn now to the beginnings of *human* societies. Here we must expect to find great differences and yet great samenesses. What are the great differences? In what ways does even a humble human society rise high above a bee-hive or a beaver village? We often hear about "the human hive" and "the instinct of the herd", but these phrases tend to exaggerate the resemblances and to slur over the differences. Man has language, making sentences, expressing judgments; animals never rise above words. Man has reason, that is to say the power of working with general ideas; animals are not known to rise above intelligence. Man has in varying measure an awareness of his own history, but that is beyond the animal except in so far as engrained promptings form part of the inheritance. Man has much more in the way of a social heritage—traditions, customs, institutions, laws, literature, and art; though there are hints of something of this sort even in an ant-hill that lasts for generations. But man in his ascent has come to be more dependent

than any animal on the heritage outside himself—the social heritage —and he has almost unlimited powers of making this better and better. Finally, man has the power, if he would only exercise it more, of guiding his conduct in reference to ideals. Animals are often kind parents, affectionate lovers, helpful to their kindred, devoted to their society, but there seems no warrant for supposing that they ever think of their duty! They may be good and kind, but they do not know what "ought" means. Perhaps we may draw a distinction between animal *behaviour* and human *conduct*; but it is not always that man rises above behaviour.

So much for differences, but let us not forget the resemblances between animal and human societies. It used to be common to compare a human society with an animal body, and to speak of the "social organism"; thus the government was compared to the nervous system, the muscles to the workers, the circulation of the blood to transport, and so on. But that was a confusion of thought; the true comparison is between a human society and an animal society. We have seen that the comparison must not be pushed too far, and another reason for being careful is that the members of an animal society are all nearly related, whereas in a human society this is usually far from being the case.

The science of societies is SOCIOLOGY, and the sociologist mainly seeks to describe the life of the society in terms of FOLK, WORK, and PLACE. Everything depends on the people themselves, what they busy themselves with, and what their surroundings are. Now these three concepts—Folk, Work, Place, which the French sociologist Le Play called *Famille, Travail, Lieu*—obviously correspond to what in biological language we call Organisms, Function, and Environment. These three fundamental ideas apply to all living creatures, and thus there must be deep resemblances between animal and human societies. For men are organisms, functioning in a particular environment, and thus they resemble animals, though they rise high above them.

If we believe that tentative men, who might be called Hominids, but not Homo, arose from a stock common to them and to the Anthropoid Apes, we are linking mankind back to creatures that are nearer the social than the solitary. Gorillas sometimes prowl about in small troups, and chimpanzees are very fond of one another's company. Although it cannot be said that any of the Anthropoid Apes live in communities, they are related to monkeys, among which the social note is often sounded. We are not, of course, including any living monkeys in man's lineage—no one believes *that* —but they represent a kindred stock, specialised for arboreal life, and they are often more than gregarious. They sometimes combine to drive off intruders; they will tear an over-venturesome eagle to pieces; they sometimes unite to raid an orchard; and they can

execute a retreat, not in a disorderly rout, but with some hint of tactics, and care for the young.

It cannot be supposed for a moment that a human society grew out of a troup of gorillas. Man made his own society. But our point is that man is solidary with mammals, among which the social note is often sounded. Think of beavers in their "village", prairie dogs in their "town", wolves in their pack, elephants in their troup, wild horses in their herd, dolphins in their "school". It is true that many mammals follow the each-for-himself line of life, but sociality has also its numerous illustrations. It is, so to speak, in the blood of the class to which Man zoologically belongs, and within which he certainly emerged. Our point is that if all mammals were like the cats that walk alone, the emergence of social man would be much more of a scientific puzzle than it is.

There is much truth in Rousseau's saying: Man did not make Society, Society made Man. For it wàs in a society that man's characteristics—such as reflectiveness, language, and gentleness—would have most chance of surviving. That is to say, new departures or variations in the direction of these estimable qualities would be most likely to be fostered in social conditions. A very clever creature might evolve as a solitary, but can we picture man's emotional and ethical and artistic evolution apart from a social heritage? In this sense society made man.

But how did the human society begin? It is not improbable, as Prof. Barell first suggested, that Man and the Himalayas arose simultaneously, towards the end of the Miocene Period, over a million years ago. Sir Arthur Smith Woodward tells us that "as the land rose, the temperature would be lowered, and some of the apes which had previously lived in the warm forest would be trapped to the north of the raised area". As the forests shrank and gave place to plains, the ancestors of man had to face living on the ground. If they had remained arboreal, or semi-arboreal like the apes, there might never have been men.

Our theory is that the early forerunners of Homo had to try a new environment, and that this was a good reason for their standing by one another socially. They were doubtless big-brained, and there is no reason to suppose that they were lacking in courage or resourcefulness, but they were adopting a new rôle as terrestrial creatures, with formidable wild beasts as competitors. Their hope was not only in their wits, but in their solidarity. Union is strength.

Another reason for clubbing together may be found in the prolonged human infancy, with its appealing helplessness, for this involved self-subordinating division of labour. For an isolated human family the struggle for existence was too keen. Thus arose a self-preservative linking of families into a simple society.

But it may be asked, Does not an otter family and many another

mammal family stand alone? Why was society so necessary for man? Part of the answer may be found in the otter's remarkable fitness for an each-for-himself mode of life. It is endowed with great vigour, nimble wits, a mastery of mountain and moorland, river and sea, a roving disposition, pla tic resourcefulness, and a capacity for thriving on very varied flesh-food. But the ancestors of men were trying a new haunt, they had more brains than brawn, they had at first no chance against lions and tigers except by outwitting them, they inclined to be gentle of heart, and, as we have said, their children were for an unusually long time helpless. Thus the pre-men, no doubt in obedience to their engrained promptings in favour of mutual aid and sociality, found safety in simple societies.

In face of great difficulties modern man often sits down and reflects on ways and means, arguing to himself that this or that change might save the situation. But we must not read ourselves back into our very distant ancestors, a million years ago, who made the first experiments in society-making. They did not combine their families because they foresaw possible advantages. They obeyed their social promptings and then discovered more or less dimly that there was strength in their weakness. And whenever the simple society began to justify itself in giving man a firmer foothold in the struggle for existence, variations in the direction of increased sociality would tend to survive. As we have noticed in regard to animals, so in man's case, the society would achieve more than the isolated family; precious individuals, like thinkers and artists, would have a chance to survive under the society shield; life would be more secure for the pioneering children and for the aged who treasured the lessons of experience; conversation would become a habit, and men would compare notes around the fire. The early societies were small beginnings, but even in the smallest there was the promise of a future still far beyond our reach, though not beyond our hopes.

THE NATURE OF HUMAN PROGRESS—In the days when science was young there were geniuses with brains as fine as any since. Personally we do not know as much as we should like to know about Eudoxus (*d.* 354 B.C.), but we have heard mathematical authorities say that he was a much bigger man than Einstein, who represents for us the present acme of human intelligence. Similarly, Archimedes (*d.* 212 B.C.) has been described as "perhaps the most perfect type of scientific intellect that has appeared in the world". Two instances will serve as well as twenty in support of the proposition that there were two thousand years ago brains as good as any since.

Our second proposition is more debatable: that the average of intellectual stature has risen. There has never been a second Aristotle, of such towering intelligence; but there has been an increase in the number of people able to understand what Aristotle

was driving at. Perhaps—as the Loeb edition and translation suggests—there has never been a better biologist than Galen, but the percentage of biologically-minded people to-day is enormously greater than it was when Galen died, about A.D. 200. There is probably—we write under correction—no poet living so great as Homer; but our point is that the percentage of the poetically-minded has risen amazingly. Let us admit that we have no sure knowledge of the percentage of minor poets, minor scientists, minor philosophers, and minor artists in old days, Greek especially; and let us also admit that part of what seems like widespread mentality to-day is only superposed and mimetic veneer. But after we have made these and other allowances we cannot rid ourselves of the commonsense conviction that the average of culture has risen. Humanity has made progress since the days of the primitive men of whom Æschylus gave such a vivid picture, living "like silly ants, beneath the ground, in hollow caves unsunned". Compared with *Homo neanderthalensis*, our ancient collateral in late glacial times, *Homo sapiens* has made progress; but the question long puzzled over is the nature of this advance.

As we have already outlined, men worthy of the name emerged gradually in the course of an evolutionary trend which began in Tree-shrews and Tarsiers, and continued through Lemurs and Marmosets, Monkeys and Apes, to tentative men. This trend was marked by such improvements as the emancipation of the hand and the elaboration of the voice; but it was especially concerned, as Elliot Smith has shown, with an enlargement and a complexifying of a cerebral area called the neopallium, characteristic of the higher mammals. As has been already stated, it has to do with visualising, attention, manipulation, learning, and the higher faculties generally. For our present purpose it makes little difference whether we think most of *Mind*-brain or *Brain*-mind, for the two aspects or realities have evolved together. Homo represented, to begin with, a large mutation either of the neopallium or of the mind, as one likes to look at it; and there is no reason to doubt that smaller mutations on the same line have been of frequent occurrence. We know them to-day as "geniuses", men and women of original mental pattern at a high power. Now it is possible that there has been a gradual raising of the qualitative and quantitative average of human brains during the last two thousand years, though no single individual has surpassed (say) Eudoxus and Archimedes. Progress might have been greater along this line if mankind had taken more eugenic care of its geniuses, and had condescended to select a little more consistently in favour of brains. Yet against the theory that man's supposed mental improvement since the time of Prometheus has depended on organic advances in cerebral complexity—we have some 9,200,000,000 nerve-cells in our brain cortex—there is the

fact that most of these organic advances take place with extreme slowness. It looks as if we must look elsewhere for the secret of recent progress.

In this connection the sociological idea is that man progresses by registering his advances outside himself. The social heritage (the environment of culture) is in its own way as important as what Galton called the "natural inheritance", whose vehicle is the germ-plasm. What is only adumbrated in ant-hill, termitary, beehive, beaver-village and the like, becomes in mankind of paramount influence. Man registers his progress outside himself in institutions, manners and customs, morals and laws, also in languages and literatures, in arts and crafts, in traditions and rituals, in permanent products also, and how much more. Is it not the improvement of this social heritage that accounts for the raising of the human mental average among civilised peoples, supposing this rise to be a fact?

That this is the whole truth is improbable, especially if it be admitted that the organic transmissibility of individually acquired modifications is more than doubtful. Before Weismann's scepticism infected most biologists it was usual to think and speak as if a son must be hereditarily the better for the careful education which his parents received; witness the old aristocratic saying that "it takes three generations to make a gentleman". It was believed that modificational improvements acquired by parents as the direct result of ameliorative peculiarities in nurture could be in some representative way entailed on their offspring. But there are few well-established facts to show that this is the main way in which organic evolution works. In face of this scepticism we do not depreciate the value of the progressive factors in the social heritage. Indeed, they should be ranked as more important than ever, if we are forced to the conclusion that their ameliorative influences have to play afresh on each generation.

But if mankind be progressing, in parts at least, and if this be not due either to the transmission of acquired characters, or to a slow variational uplift in mental ability, what, then, is happening? The open secret, we think, is this: that there has been *an increase in social susceptibility or impressionability*. Mankind seldom, if ever, breeds deliberately for mental ability; nor does he sift towards that quality with consistency or with enthusiasm. The same may be said in regard to health. But what man does more largely breed for and select for is susceptibility to the influences of the social heritage. As these influences become richer and more powerful there is an automatic increase in the nicety of the selective process. Apart from the physically rotten and the ethically rebellious, there is no type so likely to be a failure as that which is unsusceptible to the ameliorative influences of the social heritage. No doubt the social heritage is of mixed quality; but the integrative has on the whole

more staying power than the disintegrative, and so the quality of social receptivity is on the whole desirable. On this theory it cannot be said that each generation has to begin at the beginning again, in taking advantage of schools and churches, of books and art treasures, of traditions and ideals, and so on; for there is in every generation a sifting out of those who are markedly indifferent to the social heritage. The sifting or selection is neither vividly conscious nor rapidly lethal; it works automatically and gently, like many forms of Natural Selection; yet we believe that it has been the main method of progress. Impressionability to the ideal, which the social heritage always expresses, is *the* saving grace. Yet this must not merely leave us in a passive culture, like too many even of those who, as Matthew Arnold desired so strongly, are interested in the best that has been, or that is being, thought and done in the world: active participation in this, and contribution towards it, are also needed, even for the development of personal individuality and culture.

HUMAN ORIGINS

Important though the specific internal problems of biology are, throughout its varied fields, the great fact must not be overlooked, as it so often is, that our present eager inquiries, even into the origin of vertebrates, or of flowers, or into the puzzles of cell-division, are not enough; and that the largest question that can and must be asked is—what of Man? How is he evolving? We are finding out something, as the above pages indicate, of whence and how he came to be as he is; yet the supreme value of such inquiries is towards enabling us, and as soon as may be, to be finding some reasonable and practically suggestive answer to the question—Whither? Since Darwin, evolutionary studies have mainly looked back into the study of origins, and the quest of originative processes; and so far rightly and well. But it is also full time to be more and more considering the evolution of man, as still a going concern. We thus cannot be content with the records of his origins, or even the deepening interpretation of them: it is time to be utilising our knowledge towards the recognition of such evolutionary tendencies as he may show, and to the clearer appreciation of them. Are past lines of evolution still in progress? Surely so far; yet may there not need to be choice between them? Hence the need of artificial selection; since we are no longer in that age of *laissez-faire*, from which the theory of natural selection dates, and which still over-influences contemporary scientific minds. That artificial selection has its dangers, one cannot but see; and we are as yet making but few pleas for specific applications of it; yet our science must increasingly be getting ready to advise, and as soon as may be

to outline, comprehensive practical measures. For the time is not merely approaching, but actually beginning, when, if the evolutionary sciences cannot soundly advise; hasty policies—by turns revolutionary and reactionary, and with disastrous rebound either way—must each be pushed to their extremes instead—as already we have seen in neighbouring countries: and with sympathisers with each type of extremist in our own.

Let us see, then, how far a brief review of our knowledge of human origins may be outlined.

With but few broken and scattered bones and skulls, the anatomists have done wonders of reconstruction for us; so that we can wellnigh see these far-away kinsfolk as they walked the earth. Indeed, for their later phases especially, the close association of anatomy with sculpture and painting since the Renaissance, and so ably pioneered by Leonardo, Dürer, and their followers, has here for a generation past been productive; witness striking busts and statuettes of various early types, and dramatic pictures, by Cormon and others. And since such endeavours began, we have discovered how vivid and skilled an artist was early man himself, and not only as graver, but painter, and even sculptor. These discoveries are reacting strongly upon the modern artistic mind so that we have now better and better modern illustrations of these early peoples. The accelerating progress of archæological explorations and excavations has yielded such wealth of material towards understanding their ways of life that we are now obtaining a better acquaintance with these remote and early men than we yet have of some important peoples and civilisations of comparatively recent and even approximately historic date, like the Hittites, if not even the Etruscans. Early in what Alfred Russel Wallace justly called "the Wonderful Century" of scientific and technical advance, archæology developed primarily from two main initiatives. First, that scientific expedition to Egypt which has proved one of Napoleon's best achievements; and next the more arduous victory of M. Boucher de Perthes, in demonstrating to an incredulous world the vast antiquity of man, with that of his advancing civilisation too; the antiquity from the geological position of his implements, and the record of advance from the nature and progress of these. British investigators ably followed; Danes and Swedes also greatly contributed; and there were soon good workers in all western countries; so old museums found space, yet even special ones had also to arise. Material proved unexpectedly abundant, for caverns and "kitchen-middens" to excavate were more numerous than we knew; and, most encouraging and educative of all, flint implements great and small from heavy axe-heads and hammers even to daintiest "fairy arrows" were found to reward any observant rambler over the fields, as indeed one of the newer boy-scout organisations is actively verifying.

A great step to understanding these remains of antiquity was made by Sir John Evans, who clearly distinguished what had hitherto been too vaguely called the Stone Age, into two main periods, relatively Old and New, Palæolithic and Neolithic; the earlier with flaked implements, and the later enriched also by the advance to smooth-wrought and even polished ones. The flaked tools and weapons were then showing distinct progress in workmanship, from rudeness to mastery of the material; while polished neolithic implements were also associated with yet more wonderfully well-chipped ones. And since these evidences of advancing skill were at various points shown also broadly to coincide with the time-succession proved by sections of cavern floors, the archæologist was thus educated into the evolutionary pre-historian. As evolutionist he could not but realise that earliest man could not be expected to start by working flints into shaped tools, but must have begun, as a great ape may do, by hammering with stones as he found them. Yet he might soon gain sense to choose hard stones; and so at length might come on flint, and find it best of all. This of course would break with hard usage; yet it gets an edge thereby, and so begins the development of axe and scraper. Even with less severe use, the flint may again flake, and readily on the opposite side this time, so giving a true axe or knife-edge accordingly, and not infrequently a sharp point as well. With such material, that does not readily spoil with use, and even when broken may be all the better, since now with new uses, we recognise an incentive to the utilisation of flints. The first inventor would be he who got interested in hammering flints to break them, and in seeing what came of it: so might not such experimentalists and incipient inventors soon become common? What an interesting, even amusing occupation, in which the men, the women, the children would gather; at once a meeting and a school. Who would not curiously pick up and discuss these fragments? And what youths and children would not run home with theirs to try what they could do with them, and so begin educating their elders; as they happily sometimes do to this day. In such ways, then, we can hardly but imagine the beginnings of the technology of the flint age, and its mental skirmishes and popular diffusion together. It was thus not a little encouraging to find what seemed at first the convincing material evidence of such beginnings. For flints that might have been thus broken, in hammering, and thus also with edges with (or even for) further use, have been collected; and called Eoliths, as becomes what is not yet even palæolithic, but might well be earlier far. In fact for critical minds, they occur in only too great abundance; whence their reply to all the preceding: Very pretty, no doubt; but are not your eoliths of mere simple natural and accidental fracture, such as undeniably occur in nature; and which we can even experimentally reproduce by impacts,

rollings and pressures like those which they may naturally undergo? Hence a controversy of many years, as yet not fully ended, since each has reason on its side: but tending for us, as happens for the heirs of many other controversies, to a working compromise; in which all alleged "eoliths" are critically examined, yet in which at least the fittest and best adapted seem to survive. This controversy, and indeed all else of earliest and later tool-using and tool-making development, is thus central to the ecology of early man; even vividly ancestral to our own industrial age, the more since with flints in active usage man could hardly but strike fire. Enough however if we see here something of the beginnings of man's rise beyond Pithecanthropus and other precursors, and of the ways in which these are being investigated. There is, however, for biologists more in all this than archæology and pre-history; for here arise and for our own human kin and kind, many of the questions we are wont to ask as evolutionists. Thus is it not here that hand and brain must have attained not only a new, but an enduring discipline and impulse to work together, which at this epoch would obviously be of great survival value, albeit with Promethean dangers;—and with what progress beyond instinct, and ordinary life-habits too, to more and more of active intelligence, and more daring initiative? Here is a main emergence-epoch, alike for discovery and for invention, indeed that from which our own science and industry may best date their fundamental beginnings. And what a new field for human selection, and this both natural and artificial, and even sexual too, with survival of the triply fittest accordingly. We feel and follow the fascination of evolutionary questions from germs and worms to birds and flowers; but here may we not think and work our way more fully and intimately even towards these, by thus identifying ourselves with our own human kin, in and through their early beginnings?

More questions as to man of course arise, and yet more again from the inseparable inquiry into his social beginnings; but here enough to indicate the interest of such inquiries, and the practicability of advancing them. Not merely from books and museums; these are invaluable as records and as storehouses: yet of best use as sign-posts, sending us on towards direct experience and fresh inquiry. But how can this be obtained? Just as after a good nature-study lesson, and then before it too, the pupils run out, even from the picture-book, and into the wild, so set them questing over the stubble, and after the plough, for implements for their school museum. And into what school may not rough flints be imported, for a practical work-play class to shape and use them? Such super-Montessori courses are indeed beginning. And as from college the nature-student is encouraged to go yet further and more carefully over an extending region, as up through forest and over moors to

heights, and thence downhill again, and by streams and river banks to the seashore with its sands and dunes, its pools, its rocks and stones, its varied jetsam, so, too, does the archæologist: and where his finds are scanty, then all the more keenly, yet with special care. Indeed, here training and guidance are needed, for much damage has been done by unskilled ardour of research, and this of course irreparably, as notably to our caverns. In this matter the Speleological Society of Bristol University seems a model of ardour and skill together, well rewarded by success, as growing museum and publications testify, yet after them the cavern is left unexhausted, and unsoiled by debris.

AN ARCHÆOLOGICAL CENTRE AND ITS RECORD.—For many years past, at suitable situations, Marine Stations have been arising, and have amply justified themselves by their services to science, and to education as well. Archæological Stations are similarly needed, again at appropriate points. There are such points in every country; but as yet on the whole in Western Europe, the exploration of a good many of the numerous caverns of Dordogne has yielded the greatest wealth of results. Running one's finger over the map of France from Bordeaux some sixty miles eastward, one comes to the confluence of the Vezére and Dordogne rivers; and following up the former we find Les Eyzies, a small village, still with troglodytic houses with their living-rooms opening back into caverns, and so to this day continuous with the ancient past. In this district the river has deeply undercut the cliffs at many points, and this often to such enormous overhang that rain does not fall on the houses below, nor even on the Eyzies chateau roof, save when blown in. Here then, between caverns dissolved out by subterranean tributary streamlets, and the overhanging cliffs cut by the river, we have the caverns often opening upon long sheltered spaces of terrace, now left high and dry above the river-level. These afforded a combination of cavern and safety behind, with rain-free shelter in front, so in fact dwelling advantages the best that early man may anywhere have found. So here, since early quaternary times, there has been a succession of racial types and social formations, each and all of course represented elsewhere, and sometimes more fully, yet nowhere with more approach to completeness of series. Imagine one of these well-cut sections, down through a cavern floor, with its strata marked out like the irregularly spaced shelves of a tall bookcase, and arranged from below upwards and with the successive "works" of prehistory for us now to read. Projecting amid the gravel of the lowest shelf are flints as rough and dubious-looking as eoliths can be; yet besides these stick out others, far more rude than most we shall find higher up, yet surely implements of the rudest kind. Bones, too, have been left projecting; and during the excavation

ample material has been found to assure us of their nature; from elephant, rhinoceros and hippopotamus to deer; to cattle too, and horses, but not yet domesticated. There are bones, too, of tigers and lions, of cave-bears and hyenas; and to survive against these, despite such vantage, must have been no small education, alike in social combination and individual heroism, in intelligence and valour. As yet, however, no human bones have here been found, but implements indicating the Neanderthal type. This, as already described in outline, was almost fully human, yet also with distinct simian characters, witness the long skull with large face, the heavy brow ridges and receding forehead, and the lower jaw receding also, in contrast with our prominent chin, yet with substantially our dentition.

In these times, as shown by animal bones, and also by vestiges of plant life, the climate was warm; but in the next higher shelf of our section there are clear evidences of its cooling. This is indicated by diminution of the previous fauna of warm lands, and by the coming in of the shaggy mammoth and a woolly rhinoceros. Finer implements now appear, notably those adapted for the flaying, scraping and cutting of skins, as also others useful doubtless for shafting flint axe-heads and shaping javelins and spears: so the inferences are reasonable that with the cooling climate and severe winters these "Acheulians" became much more hunters than had been their predecessors, and this alike through diminishing plant-resources and need of animal food, as also of skins for clothing. Here, too, at this level we find traces of fires.

Next came the Mousterians, fully contemporary with the Great Ice Age, of which the oncoming had chilled their predecessors; since here in central France the glaciers of its considerable mountain-mass were not far away. The thick-coated mammoth and rhinoceros thus naturally survived, and the cave-bear still kept or threatened the caverns: but in addition to beef, venison and horse, an abundance of reindeer was available, with which it is not inconceivable that men may have thus first learned to domesticate animals. And if so, here is another great step, not only in material well-being, but also in intelligence, which such animal sympathies cultivate more deeply than can hunting, though that is ever rich in its exercise and impulse. We find a further advance both in tools and weapons; fleeing animals are captured by throwing the bolas, stone balls bound separately and held together by a thong; and there was also beginning the use of bone for minor implements. A new and notable fact is that the Mousterians had colouring matters, with which they appear to have adorned themselves. Above all, they had come to bury their dead, possibly with something of religious feeling and hope. Thus, in addition to the famous skull of Neanderthal, a

number of skeletons have been discovered, as notably at Spy near Liége, but also in Dordogne as well.

These Mousterians appear to have been overwhelmed, indeed in time replaced, by a new race of invaders. These were of amazingly fine human type; dolichocephalic, no longer heavily brow-ridged, but with vertical forehead and prominent chin. They were very tall, like the Patagonians to-day, and bore themselves fully erect, without the surviving slouching gait of their less fully human predecessors; and so were thus more fully fitted for their extensive expansions and conquests. The women—and doubtless their feminine ideal still more definitely—are of the extremest type of build for easy and ample maternity: indeed, may not this unusually marked contrast in figure between the sexes indicate a large survival (and possible selective development) of women of the previous race? The climate was still cold, though with receding glaciers; yet with full continuance of the reindeer, and with good hunting now possible over larger areas; also active fishing, as shown by well-made hooks. Their first group, the Aurignacians, exhibit advances in mastery of flint, and this with characteristic handlings, earlier and later; they also worked skilfully in horn and bone; and even in ivory, a great technical advance. This able as well as vigorous people increasingly destroyed or expelled the great carnivores, which had so largely kept back their predecessors from the caverns, and thus made them at least more fully their own; yet not merely for dwellings, though thus used at and near their entrance. From their burials here or outside we find them possessed of colouring matters for painting or tattooing their bodies, and also of necklaces and bracelets of teeth or of pierced shells. Their supreme achievement, however, and one of which previous peoples give no sign, was that of initiating the fine arts—of drawing—say rather engraving, of painting, and even of attaining to sculpture. These new arts and techniques at first seemed confined to the comparatively small objects of personal use and distinction, which are now treasures in museums, and justly to be admired throughout coming time. Fortunately for archæology and art-history alike, the schoolmaster of Les Eyzies, M. Peyrony, became more and more interested in the caverns which were yielding such marvels, and undertook the quest and careful exploration of others; so, penetrating the dark long passage of one of these, he had the magnificent surprise of finding in this one of the finest mural decorations of the palæolithic past—art-gallery and temple in one. Animal pictures are vigorously sketched, engraved, and even painted on wellnigh every sufficiently smooth rock-face then free from stalactitic masses; and these are still often admirably preserved, as it were under varnish or glass, by the subsequent thin deposit. Beside the art interest of all this, arises the anthropological question—to what purpose? Comparison with kindred but

recent and less gifted work by Bushmen in South Africa, and indeed other people's elsewhere, suggests a combination of magical, mystical, and practical purpose, not without parallels from modern hunting types in western civilisations also; though into these we need not go; enough that we have here to recognise evidence of high artistic quality in this remote and early civilisation. This discovery of course stirred up fresh research, and finer cavern galleries have since been found, as notably at Altamira, in the Spanish Pyrenees, of which illustrations have been published. French archæologists were by this time far too advanced to repeat the neglect of Boucher de Perthes' fundamental discoveries; so M. Peyrony was duly honoured, and set free to concentrate on further research, and to form the admirable museum which now occupies the old chateau of the village under its *abri sous roche*. But as at heart a teacher still, he has now accepted our overtures towards an archæological Vacation School, open to British and other foreign visitors, and followed by the training of some of its best students towards investigation in their own countries.

Return, however, to the Aurignacians, better known as the Cro-Magnon people, from the first discovery of their fine skulls in what is now the innyard of the Les Eyzies hotel. Better skeletons however next turned up elsewhere in Dordogne, and also at Mentone, etc;. so evidencing a fairly wide, and hinting at a probably much wider, distribution of this extraordinarily fine and gifted people.

The next phase of them, or their near kindred, is termed the Solutrien. It shows good handling of flint, with its own minor peculiarities in certain implements, but has yielded only one very marked novelty so far, that of well-made bone sewing-needles, bigger than our darning-needles, but otherwise of the same type. The fine arts continued, but without any distinctive progress.

Cold began to increase after what doubtless had been an interglacial period; in fact until the climate of Lapland is demonstrated from its flora and fauna; for besides more reindeer than ever, and the return or increase of mammoth and rhinoceros, we find the lemming, the chamois, etc., and even the arctic white bear. The great carnivores of warmer climates have naturally now vanished so the Magdaleniens—still essentially of Cro-Magnon type—now occupy their caverns in peace. Their flint-work of course goes on, and in variety; but they are now more than ever productive in horn, bone and ivory, and adorn their implements and weapons, and what are guessed as symbols of authority (*bâtons de commandement*) with fresh originality and skill. In fact palæolithic art now attains its climax, alike for personal and domestic adornment, and also as mural decoration in the caverns. A complete sculptor's studio has lately been discovered, with works finished and in progress. Very interesting also is the discovery of what appear like the begin-

nings of written or rather engraved characters, sometimes curiously alphabetic in aspect, yet perhaps ideographic. We know from less ancient civilisation, Chinese and Egyptian especially, that drawing has given rise to writing; but it is not a little striking to find what seems this in progress in such early times. The post-glacial period now fully begins; the northern ice-sheet and the nearer glaciers alike retreat, and thus comes better climate; so that Northern Europe becomes habitable; whence folk-wanderings, faunal disappearances and migrations, and of course with forest changes, and of minor vegetation too. These gifted Magdaleniens were now mainly overpowered or expelled, at any rate substantially replaced, by the Aziliens, apparently emigrants from Spain, who appropriate their caverns, and occupy the plateaux also. They have the previous crafts, but show industrial decline, while the fine arts all but disappear. They still paint on their cavern walls, but now merely with what is rather picture-writing and ideographic (or alphabetic?) script. And next a larger migration presses upon them, and indeed largely over Europe, apparently of the same race, but now apparently from Italy, the Tardevisians. They are still good flint-workers, but apparently not in horn or bone, much less ivory.

These last of this long succession of palæolithic peoples were next pressed upon by a new race-immigration into Europe from east and north-east; people brachycephalic, thickset and sturdy. On the Baltic shores, in Denmark and as far as Scotland, we find their "Kitchen-Middens", largely of limpet and whelk shells and fish bones, yet with beef bones, etc., too. Their flints were simple, but sometimes polished, that is of neolithic type. They had domesticated the dog, as the palæolithic hunters seem to have failed to do; and they probably had cattle, if not sometimes flocks also. Their great technical distinction is to have made baked pottery, the first we find in Europe; though whether they had invented this or learned it from further east we can hardly yet say; but at any rate they have to be credited with this art henceforth so important, first for their material civilisation, and now for all subsequent archæology.

How far these strangers (Campignians) may themselves have modified the midland palæolithic people is uncertain; as new waves of migrants, akin as far as brachycephaly may indicate, seem also to have come in. At any rate long-heads and broad-heads appear mixed in varying measure. The great point is that hunting and fishing pass into a quite secondary place; pastoral and stock-breeding activities increasingly predominate. For these (Robenhausien) people have now domesticated sheep, goats, cattle, and pigs, and even the horse as well. More important still, they make clearings, and cultivate them for cereals; and so they begin, or at least prepare, our age of bread, for which too, in whatever form, they would have ample milk, and probably butter. They seem to have made but little

use of the caverns, which, indeed, they may well have despised as dwellings, since they could not only build good huts, and increase them up to villages, but fortify them against the surviving palæolithic aborigines; indeed up to the great entrenched camps of which the ramparts and dykes still survive over Europe and in our own islands. Where lakes or fluviatile conditions were favourable, or sometimes even in marshes, they constructed great lake-dwellings, or rather lake-villages, now so well known in Switzerland, and on a smaller scale in Britain too. An additional great source of strength lay in their inter-communitary commerce, with established tracks and paths.

They wove tissues for garments, and made pottery: and, with their cult of the dead—and what other ideals and ideas we know not—they erected megalithic monuments and colossal mounds. Being as yet without metals, they were still dependent upon flint for tools and weapons. Yet while still retaining the old and essential palæolithic technique for ordinary purposes, and often developing it, as for arrowheads and more, they also gave the enormous expenditure of time and labour required for polishing them. Axes and clubs, daggers and arrowheads, chisels, scrapers, etc., were thus brought to the amazingly perfect surface which every museum shows.

Much of this long succession of early cultures and civilisations—for such they truly were—may plainly be made out in the sections of the Les Eyzies cavern-floors, as well as in fuller detail in its excellent museum; whence its special suitability as a centre for studies, and its selection for descriptive outline here accordingly; without attempt to cover the ever-increasing fields of research. Indeed above and beyond all these phases we come to the age of bronze, with which our historic age begins, though yet so dimly. So even from then, even if not earlier, and to this day, the village life has gone on, and this sometimes, over Dordogne indeed, with suggestions of organic heredity, for occasionally the Cro-Magnon and other types seem to reappear. Above all, here is a yet greater tradition of social heritages, still only beginning to be deciphered—each phase indeed, in time promising a veritable museum-gallery in itself; and in their cavern or terrace superposition to be read upwards, as the accumulating shelves and volumes of prehistory. How this favourably-situated little village has been of old a centre for its region, as this apparently for France, as she so much for Western Europe—and through times immeasurably earlier and longer than those of all historic cities—is a thought worth pondering. Nowhere else can we so clearly and fully visualise the long evolution of humanity, in its ever-renewing struggle for existence, yet culture of existence too. In strict classification the lower palœolithic men were not of our species (*Homo sapiens*), since still in important ways

too apelike, and thus rightly a distinct species (*Homo neanderthalensis*). The magnificent Cro-Magnon type, however, with not only stature and form superior to our own, but with brain as much larger than ours as is ours compared to those of the humbler extant races, might well have given himself the highest specific rank, had he but developed science to match his art; yet we have just seen him and his fellows go down before a race organically less gifted, but which had acquired the overpowering advantage of the agricultural life over the hunting culture, in many ways more brilliant. Here, indeed, may there not be the very origin and rise of our folk-tales of victories of the dwarfs over the giants?—for here we have just been seeing Jack thus rewarded, for planting his homely beanstalk; so not only surviving against the giant, but winning his kingdom and palace, his treasure and daughter too; and thus in various ways as a survival of the fitter.

This long tale of our human origins is still but a faint outline; but even the strictest biologist may find much to learn in further study of hunters and fishers as compared with pastoral and agricultural peoples. For this long and chequered pre-history of varieties of early man and our own species, and their advances respectively may throw some light upon the origins and variations he is intent to understand for lower forms.

The many acts and scenes of this long drama of origins are of course being further worked out, with interesting differences for each and every productive region, and so of course for interpretations too. And though we have above followed the presentment current in Dordogne—as still on the whole the richest and most explored, and as affording the beginnings of an archæological station for students and workers—there is also much to be learned and discovered in every country, and not least in our own isles. Not only do our great museums reward study, but not a few local ones; as notably those established by Pitt Rivers near Salisbury, and by Harold Peake at Newbury; each linking up Neolithic and Bronze Ages to the historic past. This linkage of past with present is yet more vividly demonstrated in Wales, where the researches of Prof. Fleure have brought out remarkable persistences of ancient types in our own day, both palæolithic and neolithic, and these not simply as survivals in isolated regions, but also widely recognisable throughout our modern populations. Such identifications of types supposed long vanished are being made at many points, in fact as part of a general revision of the migrations, settlements, and minglings of European peoples. This, indeed, is going so far as to be shaking—some even say shaking down—their still popular notions of racial purity, e.g. "Teutonic", "Anglo-Saxon", "Celtic", and so on; and with advances towards better understanding—let us even hope in every sense of that phrase.

THE HUNTING STAGE AND ITS SIGNIFICANCE.—Fresh results are ever appearing from the study of occupational types; and this from earliest times onward. Before the invention of rude implements, and of the art of cooking with fire, man's early predecessors, and even his ancestors, must have had a hard time; at seasons often a very hard time, yet doubtless correspondingly selective, in making their living, from whatever their hands could pick, seize, or scratch out from among the various resources yielded by the plant and minor animal life within reach, in fact all that their omnivorous dentition and digestion could cope with. So as increasing masteries of flint and fire made the hunting life possible, effective, and at length predominant, we cannot but recognise how epochal was the advance of which even its earliest cavern-floors and terraces are yielding their records; thus, on that level of hunting which we so long thought of as but earliest and rudest savagery, we are increasingly making out great and enduring beginnings of civilisation. Hence a copious and ever-increasing literature, to which Sollas' *Ancient Hunters* may be taken as example and introduction, and next, only to name one other, Carveth Reid's *Origin of Man*. This will indeed be found particularly to interest and reward the reader from its initial thesis —"Man was differentiated from the Anthropoids by becoming a Hunter"—a proposition more thoroughgoing than heretofore; and this is well argued, first from man's early geographical and biological environment, and its selective conditions, even to physical differentiation accordingly. Thence through cultural consequences and mental differentiation, with special comparisons to the psychology of the hunting *pack*, and all that may be traced from it, as in contrast to more recent doctrines, too simply derived from the herbivorous *herd*. Thus he explains many acquisitions in culture, as from progress of implements and of constructive ability, to language and to customs, as of marriage, and of property, and to amusements, even to feast and laughter; and again to war, as also from death to lamentation and burial. The moralisation of the hunter and the growth of his "imaginary environment" next lead to his further volume—on the *Origin of Superstitions*, into which we must not enter here. That much of all this hunter heritage, and of its burden too, persists, alike in contemporary civilisation and in each of us, is further argued: so this is no minor contribution to anthropology and social science, but claims to extend throughout their range. To the psychologist it teems with suggestive appeal also; yet by no means least to the biological evolutionist, since the process of selection and survival is not only well illustrated, but claimed, with apparent justice, as affording its most vividly yet continuously dramatic field in human origins and history, and perhaps in natural history too. This presentment is also of great importance towards the general treatment of occupational anthropology next to be considered,

since working out the social primacy and the persistence of its "hunter-formation" more fully than heretofore.

LATER OCCUPATIONAL DEVELOPMENTS, AND THEIR SIGNIFICANCE.—Other occupations have of course claimed their turn; but their study has been long delayed and discouraged by the too superficial treatment of conventional economists: witness their so-called "transition through hunting, pastoral, and agricultural stages" to their predominant industrial age; as if all these regional occupations were not enduring ones, and each full of anthropologic and evolutionary interest and social significance of its own. Hence one of the many difficulties of Le Play and his disciples in their renewed investigation of the nature-occupations throughout their ranges and interactions. Comprehensively to trace from simplest types and into modern times not only the hunter and the fisher, but the shepherd and the peasant in all their varieties, and from origins to outcomes, and of course the miner and the woodman too, and these in their wanderings and their interactions, has, however, been shown as an essential task before anthropologic and social studies, and these throughout geography and history, to our own places and times. For on these lines of inquiry there have been emerging more orderly methods, both of specialised inquiry and of comprehensive survey, and with interpretations accordingly; and with all these extending into many fields, formerly more or less isolated, and indeed still too much so. Anthropologist, sociologist, and psychologist, with historian, economist and more, may thus increasingly co-operate towards unravelling the long and tangled successions and inter-relations they seek to understand, and these as not so simply racial and conflicting, as many would still have us believe, but also as occupational, and cultural accordingly. In this way the long and chequered drama of human evolution may be more truly presented, and with clearer realisation of its resulting complexity of social heritage.

Every naturalist knows how much Darwin learned from his *Animals and Plants under Domestication*; yet this subject, now being rejuvenesced by Mendelian breeders, may also gain fuller light when taken along with the inter-acting natural history, pre-history, and history of their domesticator, man himself. Certainly the humanistic studies do so; for we are increasingly seeing how these animals have also domesticated man, and these plants have cultivated him. Great though have been the influences of the wild upon its strenuous and cunning hunter-folk, these others have been yet deeper and finer ones. Thus "the good shepherd" is sheep-educated, lamb-educated; the predominantly gentle Indian peoples, with their Brahmins, are cow-educated beyond all others; their magnificent princes, their amazing mahouts too, are each in his

own way not a little elephant-educated. "Chivalry", and throughout the world, from Rajput and Arab to the historic West, is rightly so termed; since so especially horse-educated; for only in later times, with the mechanisation of speed, and its pecuniarisation too, has the chivalrous given place to the "horsey". Mohammed's teaching, and his dominance as well, arose not a little from his long leadership of the camel-caravan: and so the youth of one Saul, a tent-maker at Tarsus, by "the Cilician Gates", that greatest of old caravan-junctions and passes, counts for not a little in his later life and travels, as Paul the Apostle.

CULTIVATED PLANTS AND THEIR SIGNIFICANCE.— The two foremost cereals, wheat and rice, seem merely of different money exchange-values to their buyers and sellers, and to such classical economists as still only know "the market". Yet these have also different physical and physiological values, each broadly permanent for their consumers; so these are all that arithmetic, physics, and physiology can inquire into. But beyond and above all these there have arisen throughout their long cultivated past, their very different and distinctive civilisation-results and values. How so?

CORN.—Wheat—and of course with it our kindred cereals too, oats, barley, etc.—has not only yielded the essential staff of life to our Western world, but has been also the central type and source of real life-education too, for its correspondingly fundamental social class, its peasants, farmers, squires, and lords, all so agriculturally associated. Note, then, this basal labour-experience; and as strongly, and even peculiarly, individual. Each man must plough alone and sow alone; and even when harvest comes, women are but minor assistants, and children are apt to be in the way. Thus the property of the fields becomes increasingly individual, since thus found most efficient; and the old-world spirit, with its institutions of communitary life, falls away; with individual land-hunger, and its adjustments, taking their place. The general attitude towards life, its essential organisation and law, and with these its social philosophy (often, indeed, its religious faith as well), thus becomes increasingly individualistic. Hence our old-world villages had become sources, before they were sufferers, of that individualism which has next been advanced with the mechanistic advances of the industrial age, and well-nigh perfected as these again became subordinate to the yet more potent pecuniary culture, in these times culminant.

RICE.—But now turn eastwards to the rice-fields, and realise them from Himalayas to Ceylon, and on to China, Japan, and other lands, in each and all their prime resource. A fundamentally different agriculture becomes manifest to every eye, yet is seldom more than superficially understood by us Westerners; still, take so much first.

Here, it is plain, instead of beginning with the individual field, the whole group of rice-growers are conditioned alike by their local and collective water-supply; and they have to make the best of it for all, else it may be the worse for each. Their fields must all be levelled, and banked to the right height, for holding up water in the needed quantity; and so these have gradually arisen and extended, from the vast terrace-systems ranging up the Himalayan valleys and down to the finely graded fields upon the Bengal or other plains. Then, too, beyond the skilled and harmonious adjustment of the local water supply as it naturally comes, dams are needed, to hold it up as high as may be and economise it to the full; and the construction of these reservoirs ranges from simplest "bunds", rudely built and kept up by and for the small village with its associated labour, up to great and massively built, even monumental, tanks; and thence even to artificial lakes, which sometimes, as so notably in old Ceylon, are among the most colossal engineering achievements of antiquity, still in their own way unrivalled, and thus justly admired and wondered at by our foremost modern engineers, though they have lately been learning to control far greater rivers than once filled these.

Return, however, to the field labour of rice-growers. There is needed, of course, some strenuous howking to loosen the consolidated mud-soil; but the old folks and the children can each and all take well-nigh as efficient a part as strong men, since putting the small plant into soft mud, and pressing it in lightly with the foot need small effort, though care and patience. And when reaping comes, all hands again can help, since rice is cut by handfuls. All ages and sexes have thus participated and co-operated; so the result in rice is naturally felt to be not individual, but family property; and the land as well. There is family authority and headship, but this goes by seniority; as grandfather—or if need be grandmother—presides, or parents, uncles, and aunts, down to brothers in order of age. The young married couples occupy or build additions; they keep together as far as may be, often to communitary families whose numbers amaze us; so naturally this distinctive rice-society has had a prime influence over whatever other cereal cultivators there may be. Here, then, is an essential outline (though of course in the merest outline) of a factor of adaptation—if not even basal determination—for the communitary family-system; and thus of the congruent institutions which are so characteristic of these Eastern peoples, and traceable throughout their manners and customs, their laws and morals; in short, their ways and thoughts. Of course the endless regional and social differentiations of all these have to be observed, investigated, and interpreted, but enough here as salient outline. And if verification by independent experiment be asked for—a fair scientific question, though hard to put in operation—here is at least

one. Rice-growing is, of course, a modern introduction into the plain of Lombardy; but after a time the peasants got dissatisfied with the property-laws and other regulations, and petitioned their Parliament accordingly. Their demands puzzled deputies and lawyers alike, as something unheard of; till suddenly a senator who had lived in China exclaimed: "Dio mio! These people are asking for Chinese institutions!" The peasants, of course, had never thought of that; yet their rice had taught them.

FURTHER INQUIRIES NEEDED.—Such concrete outline examples of this evolutionary natural history of man, this human ecology, have twofold suggestiveness; on one hand towards unifying studies usually too isolated, yet on the other towards further special inquiries. For since *The Golden Bough* has told us so much for the human significance of corn, yet all arising around its homely cultivation and uses, so we may well ask from oriental scholarship the like study of rice, and throughout its wider developments. The *Song of Hiawatha*, with his maize-plant, so familiar to many of us from childhood, has thus been a simple example of the needed and world-wide story of civilising origins and developments. Here, then, has been the long endeavour of Le Play and his disciples, from Tourville and Demolins onwards; and though some of their broad surveys and bold generalisations need revision, these have been of path-breaking service; while their methods and classifications, though still needing clearer order and fuller elaboration, are plainly in advance of most of those still prevalent, whether for earliest or modern times. Return for simplest, yet fundamental, example to the progresses of the tool, and also with it; as from rudest flints and fires up to the marvels of our international exhibitions; of which it is here significant to recall that the inspiring projector of the latter was Boucher de Perthes, the first interpreter of the former! And that their first competent classifier and organiser, dominant of them all till now, was Frederic Le Play; since also and independently inspired by interest in the evolution of occupations and their tools, and of man's life and ways through better use of them.

Such evolutionary presentments of man's progress have thus their interest for the biologist. As comparative and human anatomy, palæontology and archæology have come together, so next plant and animal ecology; and our human advances have not only their analogies with these, when even viewed and specialised on apart, but their fertile interactions, as in cultivation, and in domestication. In fact, are not anthropologist and biologist here substantially at one?

WOMAN IN EARLY PROGRESS, AND ONWARDS

Continuing the ecological outlines of our previous section into a sketch of the origins of prehistoric Civilisations, we noted the

increasingly significant part taken by Woman; and this so notably through her initiatives, in the success of neolithic agriculturists over palæotechnic hunters; a substantial victory, albeit even to this day so incomplete. Her distinctive functions in the other fundamental occupations with their regional and other varieties, with her own conditions and status accordingly, reward consideration. Thus what greater change than from the hunter's hard-worked squaw, dragging home the game, skinning it and so on, to the gentle duties of the milkmaid, to the simple milk-food with its light labour of preparation? See, too, her refining withdrawing-room, of the tent, which her wool-work furnished with cushions and carpets, as in time herself with embroidered robes further adorned with jewels. The longevity so remarkable in pastoral life, and especially as compared with the brevity of that of hunter-folk, gave time and leisure accordingly for the education of childhood and youth, and was highly favourable to cultural interests up to their highest levels; so that the venerable tales of Hebrew patriarchs and singers—sociological literature of this type at its highest—bear good evidence, though still too scanty, of this heightened status and influence of Woman. The like importance is yet more traceable in agriculture; whence Le Play's broad summary: "Where is the best land?"—"Where there are the best farmers". "And who are the best farmers?"—"Those who have got the best wives!" How so? Because the co-ordinative aptitudes of woman, so long developed through housekeeping, child-care, and family well-being generally—in short, with all-round place, work, and folk interests as compared with man's more specialised labours—find varied and well-organised outlets in and around the farmhouse; for which no better illustration from literature need be sought than the popular northern ballad of *John Grumley*. Thus it has been well remarked that the too frequent type of village household, in which the woman keeps house and garden, and may even earn outside as well, while her husband poaches and idles by turns, recalls very ancient conditions; broadly neolithic for woman and palæolithic for man respectively. Some anthropologists are said to have sometimes observed much the like at the dwelling of our local chief-peasant, commonly termed the squire's hall or laird's castle. But without visiting cottage or castle, even of the most agriculturally minded landowners at their best, this feminine co-ordination of life stands out plain before us in every home. It was we men who built the house and made its furniture; we cut the wood and dug the coals for the fire; we got the ore and smelted the iron and made the knives; we howked the clay and made the dishes; and we brought in the food, from our hunting, tillage, and seafaring; so we naturally feel very important. But who brings use out of all these things by bringing them together, as now, into the civilised meal, with her skill and cleanliness and touch of

grace? Woman, of course; thus transforming mere house to home; we men have but rough camp and bunk and mess without her. Our point, however, is not merely her gently exercised influence, at once cheering and civilising her menfolk: it is her co-ordination of our varied details into her functioning unity of them. For here is the distinctive quality of life; and this for each main step and phase throughout its evolution. In a word, though men be Lords of Action, women are Queens of Life.

In the present Industrial Age, conducted as it has been on fullest masculine lines, so with long-increasing dissipation of the energies and material resources of nature (termed "development" in the euphuistic verbiage of that pseudo-science of "political economy" which it is a main task for sociology to transform), woman has mostly had very subordinate share, as coal-pusher, factory-hand, and the like: but in recent times our incipient transition beyond palæotechnic rudeness and competitiveness, and towards neotechnic skill and co-ordination, are increasingly offering woman less uncongenial and better remunerated tasks, as nowadays so notably in clerkly situations. This proportional increase, at the expense of men, however, suggested by economy, proves women's efficiency also: and though her replacement of men is comparatively new, it is already yielding clear evidence of maturing co-ordinative powers, even towards widely responsible business management accordingly. Most forms of business, and of industries too, since more or less specialised, may doubtless retain masculine predominance; but the more instinctive feminine aptitudes, as for care of children, of sick, and aged, have been opening up the great professions of teaching and nursing. These again exhibit further developments, witness not only medicine and pharmacy, but secondary as well as primary instruction. So why not more and more in higher education too? And especially as this becomes more vital and sympathetic? In this the few examples are excellent; though openings are still rare, since too long well-obstructed to admit of any rapid increase.

The political claims of women do not, of course, come within this bio-anthropo-social field; but in any case we should maintain the importance of the evolutionary past and present of the sexes as more significant, more determinative of the future also, than can be our essentially masculine strifes for power in the political arena; though woman's services, even there, are being justified.

As to her long-debated "rights", there should, of course, be no further question of maintaining wrongs. But here it should be far more widely known than it yet is, that the foremost legal thinkers, like Duguit and others, are now discarding wholesale all our insistences upon "Rights"; although these have been, and are still, the traditional basis of civil law, from Roman times and earlier. For they are now elaborating a fresh conception of law, which substitutes,

for mere enforcement of personal rights, that of law as supervising the performance of social functions. This, of course, is nothing less than a revolution in thought, and towards practice: since with this, law is passing from holding the ring for rival support of individuals in conflict, and towards their re-adjustment as socians, efficiently co-operative in social service accordingly. This legal revolution has also old and venerable tradition and precedent behind it, since here we see the law changing from that of egoism to that of altruism; in short, from Code of restraint, and towards Evangel of help-will. This seeming excursus from our simpler themes thus justifies itself, as citing an incipient step in evolution, and one of promise: since it is upon the lines of mammalian evolution at their best, of human evolution at best also; for from earliest times onwards these are being increasingly feminised—a very different idea from the merely effeminate.

This change in law is significant for the mother-sex, above our other controversies of current thought, since heroically cutting its way through the gordian knot of past and present egoisms, and seeking to liberate and evoke all that is best in social humanity. As social science emerges anew upon the public horizon, at present so obscured by small trifles or great conflicts by turns, and both of these very largely for want of it, what better advance can it offer to all; and not only towards industrial and social progress, but towards true peace. And thus especially to woman, whose best intuitions have always been of this very kind—witness how she recalls her men-children from their petty conflicts, not by calling in the paternal magistrate on respective rights, but by evoking their better nature, and setting it to worthier tasks than war. Good judges have always desired to do justice; and the best even "seek peace", as at The Hague to-day: but now here comes Themis anew, to teach both them and us how to "ensue it".

WOMAN AS INVENTOR.—Meantime, however, the hunter's squaw—when not occupied with her cooking, skin-dressing, and domestic arts generally—including shelter-making, whence hut-building and of course furnishing too—would be going on with her gardening, and sometimes fishing. Such activities, keenly pursued and under the unending stresses of life which woman so peculiarly bears, afforded opportunities for discoveries, and even for those many inventions which the late Prof. Otis Mason, of the famous Smithsonian Institute, so admirably expounded in his *Women in Primitive Culture, Woman as Inventor*, etc. She was ever learning by experience to know the uncanny plants from the wholesome, and to remember their effects; so initiating herbalism for future medicine and pharmacy, albeit by ways later considered witchcraft. Flexible saplings are easily intertwined, and next plaited into a bag or basket, so suggestive

also for further uses, e.g. as primitive net, to catch the fish on its passage from streamlet into pool. Tough bark fibres would twist into strings, and so even to cords, whence again a start towards net-weaving, and in time to finer weaving; and even on another line of developments, towards pottery. The flint piercer for skins could be well replaced by a long pointed bone-splinter, with its roughly broken end yielding a notch, and even catch, for the coarse thread—in fact a needle, even to its incipient eye. Seeds of the best wild grasses (the future wheat and other cereals) lost in the winnowing would grow up in the richly manured soil round the cave-mouth or shelter, and thus be best worth gathering; and so, too, for kale, beans, and fruits; whence again, as Karl Pearson so well pointed out in early essays (republished in his *Chances of Death*), there began the woman's garden, which next became the initiative for our agricultural fields. She, too, with her children, would spare and domesticate the young lamb or calf that had followed the slain mother's body they had dragged into camp. Again, only the long life-toil of grinding the corn-grains could give the patience needed to polish a flint implement. In short, then, while the palæotechnic hunting culture essentially needed and evoked man's prowess and concentrated his interests, woman was meantime, in her quiet motherly way, working out the essentials of that neotechnic culture which in time, as she gradually disciplined youth to it, drove back that of the mighty hunters; indeed, inevitably so, through its advances in arts, in knowledge, and in steadiness of their application, in and through agriculture above all; and of course with the far greater population thus maintained, and less irregularly nourished too. Excellent though be all manner of game-food—venison, etc.—it bears a poor chance, taken all the year round, against porridge and corn-cakes, and especially with milk, as by and by butter and cheese.

Again, what hunter, or for that matter what boy or man of us all, would eat wild olives, or even now cultivated ones, save in extreme hunger? Who but woman would gather them green, steep out their bitterness in water changed day by day for three weeks, and then salt them for winter's supply? Who but she, with her mortar and pestle for corn-breaking, her quern for grinding, would pound the ripe olives, and so extract their oil, and then serve it in her salads of raw leaves? And next store it, and use it in cooking, with immense gain to alimentation, still fundamental throughout lands too warm and dry for milk-pastures. No wonder, then, that the greatest of past cultures, which has been fundamental to ours and in so many ways is still beyond it, kept up her name with honour—as Pallas Athena. Of course, as we generalise many women into "Woman", so likewise in Pallas was commemorated woman's intuitions, so full of civilisation-values for man's spirit, and also other of her inventions as well, as notably "Arachne's", of weaving.

Hence therefore there went that supreme procession yearly to Pallas' Temple, of maiden's graduation to womanhood, gallantly escorted; of which we have the inestimable record in the Elgin Marbles.

Enough, then, for suggestions towards the significant, and indeed often paramount, importance of woman and her work and ways in the origins of civilisation. Anthropology is probably of all sciences the one which can least be adequately worked out by men alone, seldom though their expeditions and their books show they realise this. Indeed, they often altogether overlook their masculine deficiencies of feeling and limitations of insight, even when recognising their difficulties in understanding strange manners and customs. More explorers and observers like Mary Kingsley are thus needed, and throughout all lands; and so, too, are studious interpreters, with insight towards deepening scholarship, like Jane Harrison. Happily such are coming forward, though as yet too few.

In conclusion, then, let us search out, and visualise, even to dramatisation—as at the caverns round our archæological station aforesaid, as well as in other places—the facts and interpretations of social origins, and this with something of laboratory towards experimentally recapitulating them, with suggestiveness accordingly. Here the help of woman is indispensable; and this not only to understand her own part, but man's as well. From such experience we can go back to our naturalistic ecology, as to Arachne the spider, Melissa the bee, Hestia the nest-builder; and thence forward anew into human society, with deeper because more sympathetic understanding of the psycho-ecology of the sexes. Indeed, thence back once more, even towards clearer understanding of the corresponding animal psychology; so tracing, even further than has Bergson, the rise and development of instinct and intelligence, with their respective distinctness, yet their interactions also; and for both sexes, by turns and together.

THE CHANGING STATUS OF THE SEXES.—The old-world importance attached to matrilinear descent, so natural to early conditions, in which the mother has all responsibility for the child, has long been familiar to anthropologists; among whom important writers of a past generation came to insist on early society as essentially "matriarchal". And though a strong reaction was provoked by the institutional emphasis, and even the governmental sense, of such a term—especially in the meanings which men tend to give to it—not a few reasons remain for seeking a fresh term (say matriprimal?) to express the highly important, and in various ways even predominant influences of woman in early society: as from the well-founded traditions of mother-goddesses to the substantial initiatives and contributions of woman as inventor and civiliser, and

these conspicuously in the domestic and the agricultural life; as well as educator of her children, and counsellor of the tribe, as markedly among Red Indian tribes, so far even to this day. Among other survivals, the matrilinear family system of the Nayars of S.W. India is conspicuously associated with a high status of woman, and a good level of civilisation; while its antiquity, and that in high esteem, is further confirmed by the traditions of various ancient civilisations and religions.

The later rise of the patrilinear system, and its spread as a social institution, has been clearly associated with a different theory of the rôle of the sexes. For here the dominant importance is given to the father, whose all-important seed is sown in the woman's field: a conception which goes naturally with the subordination of woman to man, and must have greatly helped to justify it, even in her own eyes. It is next of interest to note that the advancing status of woman, on the political, legal and economic levels, as well as on that of education, is broadly contemporaneous with the rise and diffusion of our present knowledge of the biological facts of parentage and of heredity, by which the sexes are now understood as fully complemental; thus correcting the excess of each of the two preceding theories, by combining the element of truth in each, and bringing these towards clearness. The element of political, economic and other crudeness in the initial conception of the organic and psychic "equality" of the sexes—though useful towards removing legal and political disabilities—is now being increasingly replaced by the comprehension of their complemental qualities, with respective predominance of each sex in its own functional ways, organic and psychic, ethical and social, as already outlined in our survey. And is not the above a good example of the broad parallelism and contemporaneity of ways of social life and biological doctrines?

SEX AND ITS SOCIAL CONTROL.—In this movement of science, the biological study of the normal evolution of sex throughout nature and in man, more or less as we have outlined in a previous chapter, remains fundamental. Yet for adequate understanding of our human conditions and our contemporary situation there have also been needed all the labours of the medical and psychiatric pathologists; and especially those of the Freudian schools. Their searching analyses and ruthless unveilings of sex-evils throughout all their intricacies, have afforded social diagnoses not a little disquieting to all our past and current conventions, indeed, demonstrating the disastrous insufficiency of these. With this a vast and increasing reading public is now familiar; for its weaker members only too much so; but on all sides is also coming clearly into view the need of social hygiene, and this with many endeavours. At simplest those of preventive medicine, but next onwards, towards nothing short

of the psychological and ethical purification of sex throughout the course of individual life and of sex-relations throughout society. Towards all this we have high examples from past traditions and disciplines of sex; and these on all forms and levels of sex-expression or of restraint, and in their various alternations. Expression is necessarily elemental, as in the organic world: and so far in the main normally: yet with that intensification and prolongation of sex throughout all seasons which has arisen with man's domestication to increased material well-being, restraints have been needed also, and these increasingly; whence even to utmost contrasted extremes as from phallic orgiast to self-mutilant ascetic, and these from antiquity to modern cases, as in India and Russia. Yet high expression and noble restraint have each great records; and we have now to readapt and coadjust these. Since sex is the veritable flowering of life, its intuitive impulses and formative influences are incipient from childhood, and potent in youth. They are determinant of adolescence, and formative of maturity; and in each and all with its appropriate psychic moods and expressions. The problem of social evolution is primarily to normalise all these, and to aid their development towards their highest. Hence then full appreciation for the high leadership of human evolution by youth as poet, and by maid as his inspirer: for on this vital spring of emotion depends not only the continuance of the race, but its higher developments as well: and these alike of intellectual and practical achievement, as manifestly of all the arts, from those of ennobled human expression to those creative of its needed environment of beauty. Hence the Olympian and Parnassian mythopoesy of Hellas at its highest; as again in later ages the idealisms of poetry and of chivalry at their best. Yet Hellas had also its epics and dramas of deepest sex-tragedies, and later ages the like as well. Hence the continual rise of moral restraints and examples, from philosophy, morals and religion, and even to vows of celibacy and asceticisms. So now once more, our opening evolutionary spiral has to be comprehensively elaborated in thought and applied in life, both socially and individually. At briefest, here is that "sublimation" which is one of the best terms introduced by the psycho-analysts; though the ideal and its practice are of course from antiquity and middle ages alike—whence the saying, ever current among students—"il faut faire passer son sexe par son cerveau". Yet with neglect of this largely its frequent failures, so often of arrest, at elemental level, and thence too readily to perversions of higher steps to corresponding falls. Hence the significance of biological examples; yet need of personal education, and of self-education above all.

CHAPTER XII

BIOLOGY IN ITS WIDER ASPECTS

THE BOOK OF NATURE.—Many of the sciences have grown out of practical lore: thus Natural History sprang from the traditions of hunters and shepherds and fishing folk; and Jacob, experimenting with his cattle, was one of the pioneer geneticists. As experience-lore grew and was critically sifted, when it was tested and summed up in formulæ, there was the emergence of sciences. These have never ceased to pay back to the practical man the debt they owe; and each often comes back with eagerness to some practical problem, old or new, well aware that it gives a fresh inspiration, even leads to higher result.

Thus, if there is any question as to the value of Natural History, for instance, it is always possible to begin at a utilitarian level and indicate its practical gifts. It has done big things for the amelioration of human life, and what Bacon called the relief of man's estate. It has helped him, not indeed to domesticate animals (for that is mainly pre-historic), but greatly to improve his breeds; it has increased his powers of exploiting the natural resources of sea and land; it has strengthened his hands against his enemies, so that the serpent that bites his heel is now in most cases reduced to the microscopically minute, and that too being increasingly conquered; it has given him control over many of his most formidable diseases, such as malaria, plague, hookworm, and bilharziasis.

Is not biology enabling man to understand himself better, in the light, for instance, of the hormones which so regulate the growth and life of the body, and even profoundly affect the health of the mind? When man cares enough, there is already at his disposal a body of secure science which would enable him in a few generations to realise the dreams of those who see visions to-day of eugenics, eutechnics, and eutopias, not forgetting eupsychics! If it were not for the immediate appeal of pottage (some of us must confess to great sympathy with Esau), there might soon be another Golden Age. Our forefathers had more goodwill than knowledge; but to-day there is more knowledge than we have awakened will-power to use. Alike in his science and in his social complexity, man has outrun his evolution as an organism—a summation which we cannot but suggest as a diagnosis of many of our present-day troubles.

But passing from what may be called the directly practical, we would ask how Natural History enriches man's mind. And first we

submit that Natural History meets the modern demand for pictures, the desire of enhanced visual life. Much of the deeper happiness of many of us, those who are eye-minded rather than ear-minded, depends on our private picture gallery, which we enjoy with our inner eye. The quaint tragedy is that so many prefer photographs to reality, and a cinematograph to observation. Yet it requires only earnestness of desire to collect a Natural History picture-gallery of masterpieces. We should all cultivate the habit of visualising and seeing things with our eyes shut. "I scrutinise Nature," Fabre said; but when we have scrutinised an interesting sight it is well to shut our eyes and see it all over again, like Wordsworth on his couch re-seeing the dancing daffodils. The more we see with our eyes shut the more will we see next time with our eyes wide open.

Our collection of interesting Natural History pictures leads on into the culture of our sense of beauty, for in animate Nature the fact of Beauty is ever insurgent. Apart from exceptions that prove the rule, like parasites and fœtuses, every living creature that man has not tampered with is in its natural surroundings a thing of beauty and a joy for ever. Not that everything is as brilliant as a peacock's feather, yet all independent unfingered living creatures are artistic harmonies, evoking the esthetic emotion. Moreover, the pictures we may collect every day are not only interesting and beautiful; they often have the thrill of the dramatic. These migrants changing their climate in a night; these winter-sleepers in their snug retreats; these mountain hares putting on a snow-white cloak; these gossamer-spiders borne in hundreds through the air on their silken parachutes—why, the whole web of life is shot through and through with threads of drama. We were told in childhood of the fairy gold that turned by morning into withered leaves; but when we know even a little about the vast work of the summer foliage, of its surrender of its hard-won food-material from leaf to store in stem, of the breaking down of the leaf-pigments from green to red and gold, and thus with new beauty before ashes, and of the foisting off of the dead leaf, and thus after the bandaging of the wound, we get a fuller glimpse of the drama of autumn, with its "flowers of the forest". The withering leaves we gather are thus indeed turning into fairy gold! And though they moulder, they make the soil on which their successors rise anew.

Another gift we owe to Natural History, to reading in Nature's book, consists of great ideas which enrich man's mind. There is the idea of individual development, the " minting and coining of the chick out of the egg", as Harvey said, a process entirely different from anything outside the realm of organisms. There is the idea of the perpetual circulation of matter, from one embodiment or incarnation to another; and there is the idea of evolution, more clearly illustrated among living creatures than elsewhere—a scientific idea

that is liberating man's intelligence more than any other, even towards a fuller vision of his own life.

As a discipline for the mind, Natural History is very different from the exacter sciences, of mathematics and physics; but it has educative value of its own. It engenders not only the habit of observation, but a peculiar subtlety, a deepening judgment, in its revelation of intricate inter-relations and unending consequences. Animate Nature is a rare Euclid; it bristles with unsolved problems; it provokes man into questions. Natural History is a brain-stretching discipline.

This Book of Nature is open before us, though it is not always easy to read or to turn the page. It gives us interesting pictures, beauty-feasts ever spread, many a dramatic thrill, some great ideas without which we are poor, and a supply of unsolved problems that makes life an intellectual adventure. These are five great gains; and there are two more, to make up the perfect number. Of these the first consists of certain fundamental impressions of the world of life which cannot be safely dispensed with—impressions that come not so much from inquiry as from sympathetic sojourning with living creatures in the country. As Walt Whitman said, "There was a child went forth every day, and what that child saw became part of him for a day, or for a year, or for stretching cycles of years." Nothing in the world can take the place of these deep impressions, as of growing, developing, multiplying, entailing, struggling, changing. Organisms cannot be safely nurtured on mechanisms merely. Wonder-mongering may sometimes be a refuge for intelligences that will not exert themselves; but when we get close to the Magnalia Naturæ most of us are inclined to say: This is too wonderful for me! In Natural History, as elsewhere, perhaps more than elsewhere, what Coleridge said holds good: "All knowledge begins and ends with wonder; but while the first wonder is the child of ignorance, the second is the parent of adoration," as poet and mystic have ever known.

There is a seventh gain that comes from reading in the Book—the Bible—of Nature; and that is moral encouragement. Nature is almost all for health and almost all for beauty; the exceptions are warnings to man—warnings against giving up struggling, warnings against the unlit lamp and the ungirt loin. Animals are not consciously moral agents; they cannot be credited with the concept of duty; but they have the raw materials of the primordial virtues—control, courage, self-subordination, parental care, kin-sympathy, and often each to sacrifice. No doubt there are queer ongoings in some corners of the realm of organisms; but there are dominant trends whose momentum is with man at his best. For man is grounded in the pre-human; he is no moral Melchisedek "without descent"; his being includes strands of goodness, transmuted in a new

synthesis, which were young in life in the days we now call old, unnumbered millions of years ago.

THE CULTURAL VALUE OF NATURAL HISTORY

Much has been said, and well said, in recent years in regard to the contributions which biological science is making to "the relief of man's estate". Does it not help him in his exploitation of Nature, to get more fish out of the sea, and to make two blades of grass grow where one grew before? Does it not strengthen his hands against his enemies, so that the serpent that bites his heel is becoming more and more minute, and many diseases, like those caused by hookworm and Bilharzia, the malaria organism and the diphtheria microbe, are shrinking every year.

Is not Biology enabling man to understand himself better, in the light, for instance, of the hormones that regulate the life of the body? Is not applied Biology bringing man nearer the attainment of that positive health which is characteristic of Wild Nature? More than that, has not Biology given man a new policy—the betterment of organism, functioning and environment (Folk, Work, and Place), more definite concrete ideals in the light of which he can guide his own evolution. Biology has contributed to man's wealth and health; new knowledge has given him new power. When he cares enough, he has science enough to ameliorate the generations yet unborn.

But, passing from these practical gifts, let us think again of another kind of value, not less important, the enrichment of the mind, the development of the spirit of man. In other words, let us inquire into the culture-value of Natural History, using that old-fashioned term in its widest sense.

If we may re-emphasise the ways in which Natural History contributes to our mental culture, the first is in giving us pictures that are treasures. No doubt the shepherd has his simple picture of the countryside, but the eye sees what it brings with it the power of seeing; and well-informed vision is richest and clearest. So the Natural History picture-gallery is full of masterpieces. There, for instance, in sombre colours, is the picture of life in the great abysses of the ocean. The floor of the Deep Sea shows vast undulating plains like sand-dunes, but covered with slimy mud. No scenery, no sound, no vegetation, not even rottenness. But many animals have colonised these inhospitable depths, some anchored, others slowly swimming, as if half asleep, and others walking delicately with stilt-like legs on the treacherous ooze. Sluggish existences there, devouring one another in a grim sequence of reincarnations, the last link in the chain depending on the ceaseless snow-shower of moribund minutiæ

sinking through the miles of water from the surface overhead. There is enormous pressure, many tons on every square inch of the body, but the tissues are so interpenetrated by water that the pressure is not felt. The current of life flows slowly and centenarians flourish. There is no light, save the fitful gleams of luminescence from fixed animals that sparkle like Christmas trees, and from free-swimmers gliding slowly past like illuminated miniature gondolas. Otherwise utter darkness. Also intense cold, near the freezing-point, due to the down-sinking of icy water from the Polar regions. What an eerie world, covering a hundred million square miles, more than half of the Earth's whole surface, a world of eternal night and eternal winter, soundless, stagnant, and monotonous, a plantless world with a stern struggle for existence.

In the second place, in addition to pictures of thrilling interest, Natural History affords a means of cultivating the esthetic sense. For while it is a defensible thesis that every fully-formed wild creature, living an independent life, bears the hall-mark of beauty, it cannot be denied that some are more beautiful than others. That is to say, they excite the esthetic thrill more readily, for we cannot get past the definition that a thing of beauty is a joy for ever. There is an objective basis in organic beauty, for form-beauty rests on the rhythmic orderliness of normal growth, and colour-beauty is due to the by-products of wholesome and harmonious living, and movement-beauty consists of eurhythmic self-expressions, a melody of motion, from which all the discord of awkwardness has been sifted out. But there is easy beauty, like the peacock's, and difficult beauty, like the snake's; and Natural History is a discipline in esthetic emotion. The world of living creatures is crowded with beauty, and man must give himself lessons in appreciation, just as in the case of paintings and music. He must not allow his admiration to be baulked by conventionality or prejudice, or by some sinister or superstitious association. He must be a student in Nature's school, till he finds naught common on the earth. Some people are quite sincere in denying the beauty of the hippopotamus, but this usually means that they have not seen it in its native setting, or that they have not been patient enough to scrutinise it with the eyes of the author of Book of Job:

"Great behemoth, see him with his ruddy hide, in the shade of the lotuses, in the covert of the reeds and fens. His strength is in his loins; his force is in the sinews of his belly; the muscles of his thighs are knit together. His bones are pipes of brass; his limbs are like bars of iron; he is the chief of the ways of God."

The sense of beauty is one of the enrichments of life, and the study of Natural History affords fine opportunities for its culture. There is no risk of the cold light of science hurting the esthetic emotion, for the more we know of a beautiful thing the greater is

our enjoyment. The esthetic emotion has its sensory thrill, but it is strengthened by facts and ideas, by associations and memories, and it strikes the harp-strings of the imagination. Thus William Blake wrote:

> And before my way a frowning thistle implores my stay,
> What to others a trifle appears
> Fills me full of smiles or tears;
> For double the vision my eyes do see,
> And a double vision is always with me.
> With my inward eye, 'tis an old man grey,
> With my outward, a thistle across my way.

There is, we say, no risk of science dulling the sense of beauty. He loveth best who knoweth most. Make a bouquet of leaves withered in the autumn, "the flowers of the forest", as they may well be called. Take the leaves of the wild cherry and the horse chestnut, the maple and the mountain ash, and add those of the bramble and the vine; what a beauty-feast. But let us think a little of the fatigue-effects that follow the hard photosynthetic work throughout the summer months, let us picture the retreat of the living matter and its products into the stem, let us imagine the breaking-up of the chlorophyll complex and the frequent appearance of special pigments, like anthocyan, perhaps "beauty for ashes", let us know a little about the foisting off cushion at the base of the leaf-stalk and the bandage of cork that heals the wound. The withered leaves become not less, but more beautiful; they turn into fairy gold.

A third gift from Natural History is the stimulation of interest. It gives us glimpses of a dramatic world. It is an inexhaustible well of surprises. Perhaps we do not sufficiently educate ourselves and our children for leisure time, for which one of the most reliable and rewarding interests is the drama of life in the plant and animal world. Animate Nature is full of ongoings that angels might desire to look into. As George Meredith said: "You of any well that springs may unfold the heaven of things." The commonest sight by the wayside in the early summer is the cuckoo-spit on the grasses and herbs, a frothy ball of bubbles which some people affect to regard with repulsion. But what is the story? The young frog-hopper, a sap-sucking insect still wingless, drives its mouth-stilets into the succulent stem and has its draught of sweet juice. It soon overflows with this sweetness and then it works its hind body up and down, whipping air into the fluid. At the same time there is a little overflow of digestive ferment and a little exudation of wax from the skin, so that four things are mixed up together—sap and air, wax and ferment—and a saponaceous froth is formed which shelters the insect through the heat of the day and hides it from hungry eyes. Here there is

nothing repulsive; we are face to face with the romance of a creature that saves its life by blowing soap-bubbles. As the summer advances the insects take to wing, and we see no more of the froth-blowers. Children educated in such common sights of the country are not likely to abuse their leisure.

They say that Tennyson once lingered over the ongoings in the brook by the wayside, and, turning away at last said: "What an imagination God has." Often, in any case, in his poems, he expressed the dramatic feature that is discernible in many a familiar sight.

> To-day I saw the dragon-fly
> Come from the wells where he did lie.
>
> An inner impulse rent the veil
> Of his old husk; from head to tail
> Came out clear plates of sapphire mail.
>
> He dried his wings; like gauze they grew;
> Thro' crofts and pastures wet with dew
> A living flash of light he flew.

The summer-bee, short-lived martyr to extreme state-socialism, finds a patch of white clover rich in nectar. Having filled her honey-sac she makes a bee-line for home, and there gives up her treasure-trove to housekeeping workers. Whereupon, relieved of her burden, she executes a peculiar ecstatic dance on the honeycomb, tripping round and round with a short radius, sometimes for about a minute without stopping. Bystander foragers are excited by this display, and throng near her, nosing her with their feelers. They get the clue of clover perfume, and with this hint they hurry forth. Meanwhile the dancer has shifted her stage to another part of the honeycomb, where she pirouettes afresh, and by this strange performance passes the olfactory tidings to other comrades. Soon there are many visitors at the clover patch, but when the nectar is exhausted the visits automatically cease since the disappointed bee does not dance when she goes back to the hive. No honey, no dance.

Animate Nature is full of these subtleties, and they make for the enrichment and enhancement of human life. It is not that they are quaint pieces of information; it is rather that they give us glimpses into the heart of things. They suggest Walt Whitman's exclamation: "Prais'd be the fathomless universe, for life and joy, for objects and knowledge curious."

Another great gain is to be found in the big ideas of Natural History, the biggest of all being Organic Evolution. From simple primordial organisms in a Pre-Cambrian Sea have come all the living creatures we know, including ourselves. By natural processes of changing and entailing, sifting and singling, such as can be studied in operation to-day, there has evolved in the course of hundreds of

millions of years the rich world of life. Not by the unpacking of something given at the outset, but by a unique creativeness, there has been a ceaseless emergence of the new, a succession of tentatives that sometimes blazed a fresh path, yet sometimes led nowhere. Without haste, without rest, new patterns were woven, and it may have taken half a million years to fashion a feather. It is not that one type of animal was transformed into another, that would be magic; it was rather that an old type produced variants which continued the new departure in their offspring—a process that went on until, perhaps, a new position of stability was secured. The new and the old seem often to have lived together, or the new may have pushed on into an unoccupied area. Gradually, however, in most cases, the old order changed, giving place to the new. We can study these new departures or variations to-day, sometimes small and fluctuating—the Proteus creeps; sometimes large and brusque—the Proteus leaps. Modern Biology gives us glimpses of *Natura saltatrix* with daring experiments in self-expression. And through it all there is the winnowing of the struggle for existence—sometimes rough, often subtle, a winnowing that is never random, but is in relation to an already woven web of life or system of inter-relations. It is this discriminate sifting in relation to what has been already established that prevents retrogression, except in parasites and the like, and that allows of the separation not merely of the sheep from the goats, but of those saying Shibboleth from those who can only say Sibboleth. And we miss part of the secret of Evolution if we do not realise that the organism is not a passive item sifted in a callous mesh; it is an elbowing living creature, determined to play its own hand of hereditary cards. It trades with time and trafficks with circumstance.

The broadest fact is the most eloquent of all, that as age succeeded age there emerged creatures with more fullness and freedom of life, and with increasing expression of mind. Before there were any backboned animals there were backboneless animals; and similarly fishes gave rise to amphibians, and amphibians to reptiles, and reptiles to birds and mammals, until at last arose the man. There have been strange eddies in the stream of life, often hauntingly beautiful; there have been culs-de-sac or blind alleys on the path of life, leading to nothing higher, as in the case of sponges; there have even been retrogressions, as in the case of parasites and sedentary animals; but organic evolution has been, on the whole, what man must call progressive. If this word is too human in its implication some other of similar significance must be invented. The trend of organic evolution is towards integration, that is to say towards creatures that are more harmonised, unified, and controlled than their predecessors.

As is painfully obvious, the term evolution is overworked, for it is

applied to the origin of stellar systems from a nebula, to the differentiation of different kinds of elements from protons and electrons, to the succession of climates and scenery upon the earth, to the evolution of mind, man, morals, religions, and societies; and to avoid fallacy we have suggested that the term "evolution" should always be prefixed by some adjective, like cosmic, chemical, organic, or human, and so forth, for it is certainly not the same process throughout. Yet there is a common idea at all levels—evolution is a process of Continuous Natural Becoming in which the new emerges out of the old under the operation of knowable factors. So we must not think of the idea of Evolution as if it were simply a biological theory or formula, for it is much more. It is a way of looking at things—the scientific way of expressing how things have come to be as they are. It has proved itself to be an indispensable organon in thought, and our point is that the idea is best illustrated in the realm of organisms. Those who work with the idea will be saved from many a pitfall, if they have first studied it deeply and patiently in its Natural History expression.

Charles Darwin was born on the same day and in the same year as Abraham Lincoln, February 12, 1809, and he resembled Lincoln in working for freedom. Speaking of his first impression of the *Origin of Species*, Sir Francis Galton tells us that his dominant feeling was one of *freedom*. In what way was Darwin a great liberator? First, because he showed that some of the problems of origins, which had been regarded as hopeless, were amenable to scientific treatment. Second, because he won freedom for the application of the evolution formula to man as well as to other creatures, and to emotions as well as to motions. He was one of the founders of genetic psychology, which, though still young, is making for the increased freedom of man's mind. We mean not only an intellectual freedom from obscurities, but a practical freedom as well; for the more we know of individual development and racial evolution, the more we can control the future. The truth that is Darwinism shares with all truth the power of setting us free. It is safe to say that the idea of Evolution, best studied in connection with Natural History, has done more than any other idea for the emancipation of man's mind.

Another central idea in Natural History is the idea of interrelations in the web of life. The life-circle of one organism intersects the circles of many other organisms of different kinds. This is a central Darwinian idea, the correlation of organisms, seen by Darwin more vividly than by any other naturalist before or since. When it grips our mind it is an enrichment. What does the idea imply? It means that nothing lives or dies to itself. As John Locke said, everything is a retainer to some other part of Nature. The earthworms plough the fields and plant trees; the bees and the flowers they visit are as hand and glove; the minnow nurses the

young freshwater mussels, and the mussel nurses the young bitterlings; the water-wagtail, in swallowing the small water-snails that harbour the larvæ of the liver-fluke, is helping the sheep-farmer; the squirrel has its share in making the harvest a success. Suppose that the glory that was Greece was partly dimmed by malaria; the disease is sown by mosquitoes; the larval mosquitoes in the water are very effectively checked by minnows. Ye gods and little fishes!

Many of us are familiar with the "death-watch" beetles that make tapping noises on the wainscot, the male insect thumping his head against the wood as a signal to his desired mate. The larval death-watches bore in wood and other dry materials, including books—poor food. Now it has been shown that the beginning of the digestive part of the grub's food-canal bears two minute pouches which are crammed with yeast-cells. These probably effect the fermentation of the dry-as-dust food, and it may be said of many insects that they are peripatetic breweries. In most of these the egg-shell includes yeast-cells along with the egg, and these multiply as development goes on. But Prof. Buchner found that there are no yeast-plants in the eggs of the death-watch, though the young grubs always contain them in abundance. How is this puzzle solved? The solution is very striking. Associated with the egg-laying apparatus in the female death-watch there are two minute reservoirs opening to the exterior, and these are full of yeast-plants. When an egg is laid, some yeast is expelled from the reservoirs and it adheres to the rough outer surface of the shell. When the beetle grub, developing from the egg, is ready to hatch out, it nibbles at the egg-shell, and thus its food-canal is infected and eventually stocked with yeast-plants. Of course, a very little leaven goes a long way with a larval death-watch. If this stood alone it would be a curiosity of Natural History, but such linkages are frequent and may even be called characteristic of Animate Nature.

As a fifth contribution to Culture may be ranked the array of brain-stretching problems which the study of Natural History provides. It cannot be maintained that Natural History offers the same discipline in resolute thinking that may be found in an exact science such as mathematics and physics, but it has a discipline of its own, that tends to develop sound judgment. Animate Nature is a rare Euclid. It bristles with unsolved problems. No one can tell us why a cell divides into two, or how a ferment works, or what comes about in the fertilisation of an egg, or how the obvious complexity of a chick is minted and coined out of the apparent simplicity of a drop of living matter lying on the top of the yolk; and yet there is a library of books on each of these subjects.

Or to pass to less fundamental questions, the naturalist is far from understanding how sea-swallows transported for a thousand miles in closed baskets into previously unvisited seas are able, in

some cases, to find their way back to their nests; or how it is that many a plant and animal may pass into a state of suspended animation, so thorough that the body is brittle, and yet survive; or how instinctive behaviour was evolved; or how from a common breeding-place in the far Atlantic the larvæ of the American eel move westwards and those of the European eel move eastwards, each to the continent where its parents were nurtured.

Poincaré once remarked that if the earth had been beclouded and the stars hidden, man would have remained much longer in intellectual bewilderment, but from the contemplation of the heavens he got his first ideas of orderly uniformities, helped, no doubt in certain countries, by the regular sequence of the seasons. Can it be said that the routine of life has forced other questions on Man, the solution or partial solution of which has meant a new world? Perhaps there has been nothing in Natural History so epoch-making as Newton's linkage of the falling apple to the distant moon in one great law, but we must not forget that in Animate as well as in non-living Nature Man has continually pushed the question: "Whence?" and that this has led him to the concepts of development and evolution. Perhaps it is not unfair to say that the laws of the conservation of matter and energy in the physical universe have their analogues in the world of life in the scientific concept of the continuity of generations, to wit, heredity, and in Liebig's great idea of the circulation of matter from one embodiment or incarnation to another. The air and the soil-water are bound by sunbeams into leaves and flowers; all flesh is grass and all fish diatom; and the dust that was once enchanted in a living body may enter the endless cycle once more, though a long circuit first be fetched.

Except during the Dark Ages, that vicious parenthesis in man's intellectual development, there has been in regard to the realm of organisms, as well as in regard to the domain of things, a ceaseless pushing of the question: *How does this work?* and it was a new world when Lavoisier, helped by Priestley's discovery or re-discovery of oxygen, placed the living mouse beside the lighted candle, and showed that both were burning. That was the beginning of biochemistry. Henceforth the emblem of the living organism became the burning bush, always aflame yet not consumed. This again was the discovery of a new world, still being explored with the question *How?* as torch.

Our point is that to a certain bent of mind, the realm of organisms is full of marks of interrogation—brain-stretching problems; and that the attempts to solve these have been of profound importance in the intellectual development of mankind, and must continue to be provocative.

We have spoken of interesting pictures, of the beautiful, of the dramatic, of big ideas, and of brain-stretching problems, but it is

perhaps useful to distinguish a sixth contribution which sojourning with living creatures has made to man's culture. It is a more universal contribution, for all are not expert in handling big ideas, and comparatively few men, after all, have been makers of new knowledge in a big way. We refer to the deep impressions which everyone should gain from being at home in the world of life; impressions, for instance, of growing, multiplying, and developing, of changing, entailing, and sifting. Even when these deep impressions remain undefined, they are of fundamental value. They are indispensable parts of our mental furnishing, and they cannot be replaced by anything else. Other things equal, one would always trust the judgment of a country-bred statesman more than that of one wholly urban, for the man who is at home in the country has the deep impressions of growing and developing which cannot be safely dispensed with by those who would legislate for human life. Especially in a necessarily mechanical age, it is folly to allow our children to grow up out of touch with living Nature. This is not a question of educational opinion; it is matter of life and death. It was said long ago that "Man does not live by bread alone"; that was a warning against biologisms, against forgetting the soul. But there is a complementary warning: "Organisms cannot be nurtured on mechanisms only." That is a warning against materialisms, against forgetting the life.

Dare we go a step further and say that just as nothing can take the place of the star-strewn sky in impressing us with the fact that we are citizens of no mean city, so from the envisaging of life we get a feeling of the wonder of the world without which we are poor.

> What is this life if, full of care,
> We have no time to stand and stare?

We come, in conclusion, to the seventh contribution which Natural History makes to culture. It strikes an ethical note. To many thinkers of diverse schools it has seemed clear that man can find in Animate Nature some guidance to help him in the conduct of his own affairs. Some would call the realm of organisms a great series of experiments with life, many of them extraordinarily instructive; and this matter-of-fact view is practically the same as that which regards Nature as a book or revelation. Is anything plainer in the drama of animal life than the condemnation of the unlit lamp and the ungirt loin.

> For life is not as idle ore,
> But iron dug from central gloom
> And heated hot with burning fears,
> And dipp't in baths of hissing tears,
> And battered by the shocks of doom
> To shape and use.

By struggle good things are won; without struggle they are lost.

> Behold the life of ease, it drifts.
> The sharpened life commands its course:
> She winnows, winnows roughly, sifts,
> To dip her chosen in her source,
> Contention is the vital force
> Whence pluck they brain, her prize of gifts.

Cutting deep into the problems of modern life are the lessons of Nature—the Nemesis of parasitism, for it spells degeneracy; the dangers of sluggish existence, when the environment is so apt to master the organism; and the risks that are run whenever Nature's sifting ceases, and is not replaced by some higher form of selection. A society that dispenses with sifting is working out its own doom.

An ant-hill may be taken as an instance of one of Nature's warnings. As an exhibition of social organisation, of division of labour, of efficiency, and of instinctive self-subordination and loyalty, it is admirable; but whenever we peer into it we discover the seamy side. The ant-community depends on a reproductive caste, the several queens and males amid the multitudinous ranks of the workers in a large ant-hill. The work of the ant-hill is discharged by a huge body of more or less sterile, sex-repressed females. In a bee-hive, which is not far removed from some of the communities of wild bees, we observe the sterility of the great majority; the short duration of adult life—about six weeks—in the summer worker-bees; the presence of a large number of non-productive, though by no means idle, males; the cumulative cold-shouldering of these drones towards the end of the season, and the frequent occurrence of a final massacre. Heaven help us from going to the ants or to the bees!

No one will suggest any facile argument from honey-bees to what is often unadvisedly called the human hive, for the organisms and their social bonds are utterly different; yet it seems legitimate to look into Nature's great experimental station for warning and even for encouragement. We might refer in further illustration to the success that attends those wild animals that play, such as kittens and puppies, lambs and kids, from a study of which man has learned to understand more clearly the biological and psychological importance of his own playing. Again, it is impossible not to be impressed by the success that attends the small families among animals well-equipped in body and mind. Types that economise in reproductivity have rarely anything to fear from those that spawn.

There is yet another way in which Natural History touches us as moral agents. Ethical conduct implies control in reference to ideals, and since we have no evidence that warrants us in crediting animals

with general ideas, we cannot regard them as ethical in the strict sense. Their behaviour does not rise into conduct, whereas man's normally does. But while animals cannot be called ethical, they have the raw materials of some of the virtues--such as courage, sympathy, affection, and self-subordination. These strands are of ancient origin, and they have entered into Man's fabric, though doubtless transmuted in the new synthesis that emerged when man became man, a new creature of rational discourse. But there is interest and more than interest in the fact that strands of primordial virtue have formed part of man's pre-human inheritance. In bygone days we heard much about original sin; we need to hear more about original righteousness. Man cannot be a moral Melchisedek, "without descent", and it is of value to recognise that there is momentum with him at his best, as well as with him at his worst. As Tennyson said, we have "to let the ape and tiger die"; but we have also to let animal courage and animal sympathy live.

We have just been hinting at the evolution of ethics, but, finally, there is another inquiry not to be forgotten—the ethics of evolution. To some who have looked at the process of organic evolution through spectacles of prejudice, it has seemed to be abhorrent—"red in tooth and claw with rapine", "every hedgerow shrieking with bloodshed", "an incessant Hobbesian warfare of each against all", "a dismal cockpit", "a deadly race in which each is for himself and elimination takes the hindmost". But this is a nightmare view of Animate Nature. For while the whole scheme certainly depends on successive re-incarnations, and while struggle and sifting must be recognised as not only conspicuous but essential, there is another side to the picture. The struggle for existence is rarely an internecine battle around the platter of subsistence, it is often describable as an endeavour after well-being. As Darwin clearly indicated, the struggle for existence includes all the answers-back that living creatures make to environing difficulties and limitations. It includes the softer quilting of the nest as well as the sharpening of teeth and claws; it includes parental care and mutual aid as well as aggressive elbowing and fierce competition.

What seems to stand out clearly is that Nature gives premier places to creatures like Birds and Mammals which are good lovers and good parents, which practise, all unknown to themselves, what we call self-subordination and the other-regarding virtues. To speak metaphorically, Nature is all for health and all for beauty; but to that we must add that she often leans her weight in favour of warm-hearted kindliness and nimble wits. To speak more scientifically, there is a survival value, not only in positive health and the harmony of constitution which expresses itself as beauty, but also in parental care and kin-sympathy, and in the clear-headedness which often goes with vigour. Thus it seems not far-fetched but true to say that

there are trends in Organic Evolution which are in line with what man at his best has always regarded as best. Nature is not against us, but for us.

MAN'S ATTITUDE TO SCIENCE

Biological and other Science has long suffered from its apparent detachment from all traditional outlooks. From homeliest and most practical minds, to those of artistic and poetic vision, and to philosophical and religious minds as well, science seems something isolated from their living interests. And as all these minds have something in common, and often more than appears, a consensus, still far too general, has arisen of natural science as something "dry". It seems inartistic and unpoetic, unpractical and thus useless, and though it has been from time to time more or less considered by philosophers, and now more than ever, this is still commonly with a highly superior air. And till lately, also, it seemed irreligious, as indeed to "fundamentalists" still. So far all these reasons and more, there is little wonder that biology has still so little place, save indeed in medicine, which practically each and all of the above types, when they need its services have to accept and obey: but seldom with understanding.

No doubt all these estimates are improving. The practical man, as agriculturist, begins to learn: as engineer, he is increasingly an applied physicist; many manufacturers are also applied chemists, and so forth.

But the poet! Though Wordsworth, Keats, and others have been revolted by science, or rather what they took for it, there has been a great succession of appreciations, such as those of Tennyson and Emerson, Goethe and Meredith, and more. Ruskin, though at times saying hard things, was a true naturalist-observer, as his best passages of nature description and his exquisite drawings alike show. And so, too, the painters he best loved, from Cox, Hunt, Turner, to the Pre-Raphaelites, were all true naturalists in their sympathetically observant way.

There is from childhood in every naturalist something of that nature-ecstasy and joy, that identification with Nature's life, which Jefferies has so expressed in his autobiographic *Story of My Heart*, though in later life this is only too readily depressed by the habitual acceptance of the duller everyday life around him, or repressed by too strictly intellectual or pedagogic routine—or often both.

BIOLOGY AND HEALTH

AS THINGS ARE.—An impressionist biological survey of our communities seems to forbid pessimism in regard to health. Children

at play, men at work in the open air, the members of a golf club, the exhibitors at a honey-show, a morning train emptying at a city terminus, the crews of the trawlers when they come into port, the jollity of a country fair—in a hundred directions we find evidence of a strong current of healthfulness in our midst. There is no warrant for an alarmist position. Yet if we take a friendly doctor with us on our survey, we soon discover that things are not quite so satisfactory as they seem; and when we correct our impressions with vital statistics we lose all our complacency. There is much disease in our midst—overflowing hospitals and asylums and overworked panel doctors; there is much venereal disease, though there are signs of alleviation and though its incidence varies greatly in different towns; there is much depressed vitality and dispiritedness, sex-mischief and sex-disharmony; there are still many forms of work that are to a considerable extent unwholesome; there are many houses that even the miracle of love can scarce make homes.

In face of these evils, there are many to ask: Who will show us any good? And it is well at the outset to recognise that there are many answers, each with its contribution. Those who feel the old ideals fading from their former powers say, for instance, that what we most need is a new heart; social renewal requires religious revival, and thereby moral renewal with it. Others say that above all we need changes in our social organisation, for we are enmeshed in a net handed down from the early industrial age—a net in which we struggle without getting free from its entanglement. Thus our best efforts are often baulked. Besides these two most frequent answers, there are others, most of them of value; but our particular concern here is with the help that *science* can give.

Man's appeal to medical knowledge is in a measure an appeal to science, and goes back to antiquity, but the wider idea of the control of life by science is modern. Bacon had it, of course, as when he spoke of science as "a rich storehouse for the glory of the creator, and *for the relief of man's estate*", or when, in reference to his "Solomon's House", he said: "The end of our foundation is the knowledge of causes and the secret motions of things to the enlargement of the bounds of human empire and the effecting of all things possible." But great steps towards such mastery have been made since Bacon's day, and it is with justified hopefulness that we invoke the aid of science to help us amid our sea of troubles. Science is for life, said Herbert Spencer, not life for science. The days of folded hands and fatalism are over; science is always *meliorist*; its watchword is: Face the facts; observe and scrutinise them; then try to understand them; control will follow. Thus in regard to health and social hygiene, we ask: What can Science do?

What can Science do for "the relief of man's estate"? But our question should rather be: What can science *not* do? Let us think

vividly for a moment of some modern achievements. Science has brought the stars to within its measurement and even weighed some of them in its balance; it has knocked to pieces what so long seemed indivisible atoms; it has mastered some of the many octaves on the long gamut of electro-magnetic radiations, using those at one end for broadcasting, and those at the other end for radio-therapy. Utilising Becquerel's great discovery of radio-activity, science detects the bullet deep buried in the bone or even brain, and sees the pearl hidden in the unopened oyster; it is beginning to see the invisible, and even from a great distance. By means of powerful electric discharges, man is now tapping the inexhaustible supply of nitrogen in the atmosphere, and using it for the synthesis of fertilisers—thus multiplying his loaves out of the thin air.

And if it be said that these illustrations of scientific achievement are in the physical world, whereas our troubles are in the world of life, we have only to recall some of the many victories that are to the credit of modern medicine with Biology at its back. The first services of bacteriology and its "germ-theory" of disease to surgery, and to medicine also—witness yellow fever practically abolished and Malaria coming under control—are now of common knowledge. So a few illustrations will here suffice.

One of the heaviest mundane clouds that has of recent years seemed spreading on the human race in warm countries is Ankylostomiasis—a wasting disease traced to a contemptible little threadworm that finds entrance into man through the skin of his bare feet. But this "hookworm" is now being practically conquered; it is easily expelled from the human body, and reinfection can be prevented—wherever man is willing—by simple sanitary precautions. Thus the clouds of "tropical depression"—implying debility, despair, and dreary premature death—are being lifted. Already in some places the incidence of hookworm disease has been reduced from about twenty-five per cent. to about three. What can Science *not* do?

Of the 30,000 or so children born every year in Cairo, 10,000 are said to be attacked by the painful and weakening disease of Bilharziasis, due to a fluke-worm, whose minute larva enters the body from the water in which the children paddle. During the Great War, when this parasitic worm (Schistosomum) was very troublesome to our soldiers in Egypt, Major Leiper unravelled its complicated life-history, and found its young stages in water-snails. More than that, he showed that if the water in which the minute free-swimming larvæ swarm is left still in cisterns and the like, the larvæ die off, so that the water is no longer infective. Bilharzia thus is theoretically conquered.

A cretinoid child, arrested in the development of its body and mind, is one of the saddest of sights. Its thyroid gland is not function-

ing properly, and progress has stopped. But it is one of the triumphs of modern medicine that the child can be released from the spell if it is treated with thyroid material from sheep or calf. Similarly, there is the insulin treatment of diabetes and, on another line, the serum-treatment of diphtheria. Ankylostomiasis, Bilharziasis, Cretinism, Diabetes—so we might continue down the alphabet of medical triumphs, not to speak of problems now worked at with increasing chance for hope. But we shall mention only one other great advance, that the British child born this year has a life-expectancy twelve years more than that of a child born a hundred years ago; and almost the whole of this improvement—unfortunately not at present continuing at the same rate of rise—was effected in little more than a generation. Our point is simply that when biological and medical science turns with all its strength beyond the advancing victories over disease to the attainment of positive health, we may reasonably expect fresh and insurgent progress.

At present, however, the biologist cannot but be impressed with the painful contrast, as regards health, between our so far civilised society and Wild Nature with which man has not interfered. In civilised society disease is rife—environmental, functional, microbic, and constitutional—meaning by disease any deteriorative and more or less disintegrative disturbance of vital processes. How depressing our modern city life, as is plainly shown by our need for "change of air", and our benefit from holidays. But in Wild Nature disease is all but unknown. Apparent exceptions to this statement leap to the mind—grouse disease, salmon disease, potato disease, larch disease, and so on; but most if not all of these apparent exceptions appear to be associated with man's interference. By over-sheltering, over-exposure, over-crowding, contamination, or some other interference, man alters the natural regime which normally makes for health. In Wild Nature pathological variations tend to be nipped in the bud; there is speedy and persistent elimination of the ineffective; healthfulness is demanded in the struggle for existence. But in civilised society there is endless compromise with the abnormal. Man's ambitions and desires are often so strong that health becomes a secondary consideration; social sentiment being strong, there is necessarily much cobbling and coddling, kind in the present, often cruel to the future; civilised man has a dulled health-conscience and weak resting "instincts". Just as an ant society may shelter individuals who cannot forage for themselves, nor even eat the food that is brought to them, so human society shelters undesirable individuals who would be speedily eliminated in non-social conditions. It is not so much the shelter of undesirables that one deplores—costly as it is; what is alarming is the permission, or even encouragement, to multiply.

Civilised society is blotched, and even too generally paled with depressed vitality or "sub-health", whereas Wild Nature is for the most part a world of exuberant vigour. There are, indeed, sluggish and parasitic animals we might think of as depressed, but the rule is a high standard of healthy activities throughout. Similarly, it is only in Mankind and in creatures he shelters that we find senility—deterioration that disintegrates the unity of the organism, the nemesis of his over-coddling, over-cobbling, and physiological bad debts. In Wild Nature there is never more than senescence. There is ageing, indeed, but no senility; for the creature that grows old is pushed off the stage by some competitive blow or environmental gust, before any marked deterioration has set in. No doubt from hour to hour we must "ripe and ripe", but it should not be beyond man's power to evade "rotting and rotting".

Sadly prominent in civilised society is the pathology of sex; in Wild Nature it is conspicuous by its rarity. There are some over-sexed animals and ugly erotic orgasms, but they are exceptional, and again are often known only in conditions of domestication. In many cases, as among birds, there is singularly beautiful courtship, and the conjugal relations are pleasant to contemplate. There are many monogamous animals, and of these not a few throughout life. But in civilised society the pathology of sex is obtrusive—witness the long-continued disgrace of prostitution; the prevalence of venereal diseases; the frequency of sensuality and degenerative sex-habits; the common occurrence of nominal celibacy; the postponement of marriage owing to lack of adequate housing, and other difficulties; and in some countries, like ours, the large number of unmarried women, a disproportion that always lowers the standard of sex-selection on the woman's part. Why should there be so much pathology of sex in civilised society? Part of the answer is no doubt, as in the contrasts already noted, that man's whole known evolution has been in process for a relatively short time, and his historic civilisation forms and phases yet shorter, as compared with the unthinkable millions of years during which disharmonies have been sifted out from Wild Nature, while, above all, that latest civilisation-phase we call the Industrial Age has so far bought its progress dear. Furthermore, as regards sex, it must be noted that civilised man is not now seasonally punctuated, as most animals are, and that animals are not in the same degree subject to the social conditions and ethical limitations which lead in man to ignoble repressions and perversions more readily than to ennobling control. But there is another factor to be recognised that sex-selection (sifting for mates) among animals has very frequently reference to vigour, agility, artistic gifts, and the like—all spelling health. This has been true in mankind also, as Darwin insisted; but one has only to look around

to see that considerations of health do not always count for much in human marriages.

From man one should expect great things as regards health; for he stands apart from the beasts of the field in his language, in his power of conceptual inference (reason), in his consciousness of his own history, and in his capacity for controlling his conduct in reference to ideals. Yet our contrast has shown that as regards healthfulness man is still muddling along!

If we are asked to formulate the largest idea that biology has to contribute to the theory of social reform, including social hygiene, we would say this: that integrative human evolution must proceed along three lines, and these in unison, if it is to be stably progressive. The three lines are on the sides of the "biological prism": Organism, Function, Environment; or, in human terms, Folk, Work, Place. The improvement of the breed is fundamental. You cannot gather grapes off thorns, or figs off thistles. Yet what is inherited must be functioned with, if it is to be realised. Even if hereditary talents cannot be increased as regards their number, they can be increasingly traded with. Next, who shall set limits to the value of environmental nurture? The good seed requires good soil. The buds of our inheritance, as Walt Whitman said, are "to be opened on the old terms". If the wan blind Proteus of the Dalmatian caves be taken young enough, it may become pigmented under appropriate illumination, and may actually develop a seeing eye. Many social reforms fail of their full fruition because it is not realised that Organism, Function, and Environment (Folk, Work, Place) must evolve together if progress is to be sure.

Towards an improvement in the positive health of the nation, many factors are contributing. (*a*) Sanitary and hygienic advances, the efforts of Health Committees and Medical Officers of Health, and the development of Preventive Medicine must be gratefully recognised. (*b*) Many teachers, clergymen, and family doctors are helping nobly towards a higher ambition of personal health and moral control. (*c*) Every man and woman of goodwill is furthering some one or other of the many movements that directly or indirectly make for health—boy scouts, girl guides, open-air clubs, gardening, sports, hobbies for leisure time, mothers and babies' clubs, women citizen associations, temperance societies, and many more, so diverse in their nature, that there is always one or another that appeals to each of us.

But we venture to submit some personal suggestions that appeal particularly to ourselves. No one can exaggerate the value of health. From childhood onwards, it is more than half-way to happiness; it unifies our whole being, which disease distracts and disrupts; it tends to be associated with healthy-mindedness; it helps us to rebel against ignoble acquiescences; it is a sensitive

touchstone of moral conduct; and its economic value is inestimable. It is said that three million working days are lost in Great Britain every year from rheumatism alone—say the equivalent of at least eight thousand unemployed. Health has survival value, for individual and for nation alike.

Now if health is of this high value, it would probably reward the Ministry of Health to discover and ordain apostles of health, at least twelve to begin with, who would be scattered over the country for its mission. We mean men and women of irradiating healthfulness, as well as keen observation, wide knowledge, and impassioned purpose, who by their daily walk and conversation, as well as by their wise and well-informed precept, would make people feel that health—positive health—is one of the most desirable things in the world, one of the saving graces of life, and correspondingly attainable.

The indirect appeal is often more potent than the direct; so our beginnings of preservation of Nature, and of beautifying-societies in town and country, from tree-planting and park-making, onwards to garden-villages and city improvements, are already showing wonders towards healthfulness. Ugly rooms, ugly houses (so terribly multiplied of late), ugly streets, ugly towns, work against health. It is easier to live a healthy life in a home than in a hovel. Beauty is a tonic, potent towards health.

It is a difficult doctrine to live up to, but the socialised and moralised criticism of expenditure may be made one of the most powerful levers of human progress. Where one has any alternative in spending money, one should spend in the direction of occupations and products that make for health. A gift of flowers is biologically better than a turned ivory ornament, and a little picture is psychologically far better than a platinum ring.

There is no blinking the fact that our communities are being weakened by lack of selection for health. Man has rightly rebelled against the crude and unsparing winnowing of Nature's regime, but he has not yet fully faced, much less organised, the needed transcendence of it by a sufficiently resolute and thought-out rational and social selection. This is the "dilemma of civilisation". As Herbert Spencer said: "Any arrangements which, in any considerable degree, prevent superiority from profiting by the rewards of superiority, or shield inferiority from the evils it entails—any arrangements that make it as well to be inferior as to be superior, are arrangements diametrically opposed to the progress of organisation and the reaching of a higher life."

It may seem to some a little thing, but great results would probably follow a more generous social recognition of the pre-eminently healthy. Baby-shows and athletic trainings show beginnings towards this, but it should not be beyond man's wit to devise more social

recognition and appreciation of health merits. The school-child never absent for five years is sometimes honoured in the newspapers, as sometimes is the old worker who has been steadily efficient throughout as many decennia; centenarians are recognised, and golden weddings are often jubilees; but we need to go far beyond all such suggestive beginnings. A parentage conscience needs to be aroused and extended throughout the community, and the old-fashioned pride in having a fine family—the oldest ambition in the world—requires to be re-awakened. The distinction between marriage and parentage must be kept in mind, but a definite, yet humane, segregation of obvious undesirables seems urgently called for, and is already at various points beginning.

It is becoming recognised as a too hazardous inactivity in modern times to allow young people to grow up without more definite instruction in the laws of health and happiness. These physiological and psychological laws of course include the facts of sex, though these must not be isolated from the problem of the all-round healthfulness of the organism. Never was there more need for biological teaching in schools, including not only much timely and thorough physiology, but a familiarity with such ideas as growing, developing, habit-forming, varying. For we are living in a mechanical age, and our educational world is still too limited by this. If our hereditary buds are to be opened aright, we must secure liberating stimuli, which include first-hand impressions of *life*.

In conclusion, the biologist is in the responsible, if fortunate, position of studying a central science. There is great and legitimate field for the mechanics, physics, and chemistry of living creatures, so he must have acquaintance with that. There is also a psychology of many animals and a sociology of a few, so he must appreciate that. And then, central to all these there is the vast and varied field of Biology itself. Hence the biologist has least excuse for partial views, because perforce he must take so many. His aim and purpose, both initial and final, must therefore be—Let is try to take all-round views.

The dominant inclinations of our times are towards wealth; yet these alone truly reach it who see this as no mere winning of money tokens, but as won through mastery of natural energies, to their economical uses and transformations. The great chemist, Sir William Ramsay, once declared that "real progress consists in learning how better to employ energy—how better to effect its transformation". This is profoundly true, and yet very limited. What is wealth without health? No doubt the curse of the poor is their poverty, but biological ideals rise beyond the transformation of physical energy to organic vigour, robust initiative, adaptation to stimulating and enriching surroundings; and these not only their own, but also the community's: Health, for short.

But much the same sort of mistake is repeated when we lay all the stress on the healthy body. For what avails it that body be fair if mind be stunted or soul be fouled. We must complete the old trilogy; of wealthy, healthy, and wise, and these in their due ascending order. We hear about the needed balance of bodily nutrition, but what of the nurture of the mind? Just as there may be Calcium starvation, so there is Beauty starvation. We must look to it that we do not shut ourselves off from the ultra-violet rays of the spirit.

But even wealthy, plus healthy, plus wise, is incomplete; for we are social organisms in our very essence, citizens of no mean city, members of the body politic, members one of another, folk working together in our given place. Thus social considerations must be supreme; the ideals of "wealthy, healthy and wise" have as yet been too individual, the opening future has to Socialise them with ever-increasing fullness.

We cannot conclude, however, without returning to ants, bees, and wasps, which have offered such promise of wisdom to the social reformer, yet show lurid warnings too. Some are fond of speaking of "the human herd", and others play with the phrase "the human hive". Each term has its meaning, of course, but they need also to be made of service in reminding us that we may pay too dear for our socialising. Let us go to the bee, for instance, so commonly upheld as an embodiment of all the virtues, save hospitality. Bees are wonderful creatures, the finest children of instinct in the world, and the social organisation of the hive is marvellous. But is it admirable for us? When we look into the matter more critically, what a very seamy side is disclosed. There is the establishment of a reproductive, non-productive caste—a loathsome idea; there is the dependence of the whole system on a huge proletariat of suppressed females, instinctively a "servile state", and largely unintelligent; there is the terrible thirling of the queen to her exaggerated maternity; and, as a bitter bathos, there is the massacre of the drones. Heaven preserve us from going to the bees!

Then the generalised moral for us is this, that even social organisation is not necessarily a good thing in itself. It requires to be scrutinised, not only in terms of wealth and health, both so conspicuous in the bee-hive, but in terms of the higher values—the good, the beautiful, and the true, with their outcome in the evolution of man's personality. "For what profit will there be if a man gains the whole world and forfeits his soul?"

PLEASURE AND PAIN IN LIFE

As to the values of pleasure and pain, philosophers have long disputed, economists have theorised, and politicians have acted on both teachings; but comparative psychology and biology, with their

more exacting disciplines, seem not yet to have reached an adequate evolutionary presentment. Yet as we break away from the apsychic convention of mechanistic biology, and follow Darwin's pioneering in his *Expression of the Emotions* upwards throughout the animal series, the extending range and deepening intensity of feeling become increasingly manifest, and this at times up to emotional expression which we cannot but realise as essentially akin to our own; as fundamentally connected with the self-maintaining and species-maintaining urges and activities, satisfactions, or failures. The correlation of the organism is towards its general well-being; and this as coenaesthesia essentially pleasurable, as the face of the sleeping babe is enough to show—for this must be surely but a typical culmination for the organic series, and not an exception to it. The child or adult when out of sorts again indicates, in the subconscious, what may next sharply arise to consciousness as pain. Hence may not—indeed, must not—pain have had great influence and impulse in the awakening of self-consciousness generally.

What idea is more familiar than that we do not appreciate good health until we experience its deterioration or disturbance? For the like reason, psychologists have often more or less ignored pleasure as normal and positive, and treated it rather as a neutral state from which pain arouses us; so essentially from its abatement or disappearance do we recognise pleasure. Such a view, however satisfactory it may seem in simple cases, like relief from toothache or seasickness, may also be supported by reference to the dulled activity, the subsidence of the joy of life, too common in mammalian adults other than our own species; but not as a real presentment of the manifestly happy immaturity of child and kitten, of puppy and lamb alike. But if we were to venture psychologically to interpret developmental characters as recapitulatory of race-history, as we so much do in embryology, have we not a saddened picture of mammalian maturity; and perhaps of that of other lines of evolution as well, as of degeneration from some early Eden of universal joy? Yet surely not for the birds, who instead of exhibiting such adult depression, show rather the opposite as they mature, unless in captivity. Indeed! are there not reasons for ascribing to the captivity of domestication no small share of the depression of active pleasure we see alike in our animals and in each other; though hardly the whole.

In any case we cannot be satisfied by a too simply physiological treatment, such as Dr. Bousfield's, in his recent *Pleasure and Pain*, for which "pain is the mental result of an increase of organic tension, within certain limits, and pleasure the result of its rate of reduction". Ably though he develops his thesis, and not without some recognition that there may be pleasures beyond abatement of tensions and their pain, he does not venture into the discussion of

these; yet such are surely the very pleasures which life most needs, to make it better worth living. Such psychology practically gets no further than did the old hedonism, if indeed as far; and perhaps for the same reason, of the prosaic depression of life in our industrial age, for which "push-pin is as good as poetry"—in Bentham's view. The high and intensely positive pleasure-consciousness of the poets—surely the most vitally developed of our species, and most anticipatory of all—is not to be ignored by science; the more since what makes all the fine arts fine is their poetic quality, of which science and philosophy at their fullest, share something too. By all means let the physician abate pain, as one real source of organic pleasure, and mental too; yet, as indeed Dr. Bousfield says, is he not most effective when he gives his patient also the active fore-pleasure of renewing health, the hopeful confidence of effective functioning anew. The philanthropist in abating other evils, should follow the like course; yet for normal life, the true joys are those of life-enhancement, alike for the race and for individual participation in it. If so, the joy of life must be at once an index of its evolution, and of the very essence of its advance. Are we thus returning to utilitarian hedonism? So far, yet not within its narrow circle; but upon the widening spiral of evolution, with possibilities indefinitely greater. Indeed why not to those divined by the seer of old—"eye hath not seen, nor ear heard, neither hath it entered into the heart of man to conceive what things Life hath prepared for them that love him". As we evolve as evolutionists, from inquirers into past origins to discerners of tendencies and possibilities, such vision may grow clearer. Of old, all faiths were mythopoetic; why not ours in turn? As explained in another section, the Olympians return anew as a rational evolutionary concept, and the Parnassian Muses as well: and both defensible, even demonstrable, more than their Greek creators clearly knew: and so for other high ideals so nobly forth-shadowed in the past, and each with its Eutopia as well. Yet as all high efforts involve a repression or sublimation of simpler functionings, and thus an element of sacrifice, there is also scope in the evolution process for the service in it of the associated pain. The question arises—what then of life in its simple and seeming passive manifestations, as in the sedentary and relatively vegetative animal types, and in the plant world itself? Yet here first take note of the ancient ascetic and mystic disciplines—Indian especially, yet not exclusively, since all lands and times have had the like. These withdraw from conscious sense, from active experience and from ordinary human contacts and their feelings, and even subordinate the high pleasures of ideation and of imagery as well. They thus concentrate their psychic life into its very centre, thereby to enter the state of mystic ecstasy. This state, so long reverently appreciated as super-

normal, even to super-saintly, and, on the other hand, too simply ignored as outside conventional psychology, has first been well appreciated by William James, and next interpreted by the Freudian psychologists, as a return to the elemental sub-consciousness of embryonic life, and that of simpler beings. Yet are not both conceptions complemental? Are they not respectively elemental and culminant in the continuity of life, and in its development throughout nature to humanity; indeed, to humanity at its highest? Is not this the state to which the great poets have attained, and throughout their vast range, as from the Book of Job to the Divine Comedy, or again in Shelley and Wordsworth, Emerson and Whitman; and is it not to this that they owe their greatness? Yet the like comes to the nature-lover, in his best moments of fullest appreciation of nature, from the sublimities of the heavens to the lofty snows and floral beauties of his mother earth. Is not this the ultimate inspiration, indeed the very soul, of all our nature-studies, and that which we share with the poets and the mystics; as at once transcendent to us, in Nature, and immanent in it and in ourselves; and these in their compenetrance and interaction, which is Life, and in the rhythmic intensification of these, which is surely of the essence of its evolution?

As poetry, like the life it voices, has varied range, varied musal inspiration and expression, as from simplest lyric to fullest music-drama-cycle, so the intellectual life has its kindred and parallel ranges; as from mathematics and throughout the sciences, to the emotioned syntheses of great philosophies, as the very word philosophy implies. Yet all these are akin to the child's first thrillings to the sunrise or the flower, and indeed have developed from them. Varied yet one is the spirit underlying the simple nature-lore of Gilbert White of Selborne, the more impassioned pages of Hudson, or the veritable ecstasy of Richard Jefferies; yet higher also within the thought of Newton or of Einstein, or the cosmic and human meditation of Kant. The epilogue to the *Origin of Species* reveals the like spirit; at times even the sober Linnæus, or the critical Huxley could not but yield to it; in a word, it pervades science, since immanent in its very nature. Here, too, we have the interest of naturalist friendships, as of old, with our teachers, as from Haeckel or Lacaze or Wallace, and to living masters of to-day; or indeed of our own lifelong collaboration. It is thus time for men of science to shake off their conventional and academic repressions, and so at once see more fully, feel more deeply, utter more openly that fundamental joy of nature in evolution which they contemplatively share; and even to know their ever-increasing practical applications and powers of controlling nature through obeying her, as their part of Creative Evolution, and as expressions of its strenuous joys, triumphant over all pains and toils.

LINKS BETWEEN BIOLOGY AND MEDICINE

In byegone days every medical practitioner was something of a naturalist. He dealt with plant "simples" and was supposed to know his "herbs"; he dealt with animal "simples", and was supposed to know his beasts. For many a century his pocket-companion was a bottle of living leeches, and so the name of the animal became the name of the profession. People said, "Send for the leech", when we should say, "Send for the doctor"; though it is not to be hastily inferred that horse-leech meant veterinarian. But the days of the animal called leech are so largely over that even the skilled staff of the hospital are not always able to decide offhand which is its business end.

Old Prescriptions.—But it may be interesting to linger for a little over the old prescriptions, in which animals were so often prominent. Most of them—say, 75 per cent.—were probably quite superstitious, but perhaps 20 per cent. had a fairly obvious reasonableness, and another 5 per cent. an unexpected justification which modern research has revealed. As to the superstitious prescriptions, rheumatic patients were told to take a black cat to bed with them, for it is rich in curative electricity—an intriguing situation. The dust of a dried magpie was used in Germany as recently as 1880 as a cure for epilepsy, and was probably as much of a cure as anything else. To lay an open pickled herring on the soles of the feet on going to bed was deemed a cure for swollen legs, but it was never popular among thrifty Scots, who could not but think that an internal application must be better. There are hundreds of these superstitious prescriptions.

The second kind of animal prescription is that with an apparent reasonableness. We can understand that decoctions of ants might be of some use, e.g. in weeding the flora of the intestine, for ants are rich in formic acid, which is notably antiseptic. Even in these enlightened days—which mean, of course, to some extent, more skilfully disguised superstitions—we have known of a man with bad rheumatism in his arm subject himself to a ferocious attack from hive-bees, whose stings, including formic acid injection, did much good. Without more data, it would be rash to stake more on it than on a prescription of nettle soup, where something like formic acid is said to operate, but it would be very hasty to brush aside such old prescriptions as quite lacking in reasonable promise. We can understand the effectiveness of a diet of snails—for the snail and the toothsome periwinkle, between them "the poor man's oyster", are rich in digestive ferments, which might well be useful. It is not surprising that powdered pearls—a dose for the profiteer of ancient days--might be of some service, for pearls are made of

lime, and some fifty years ago there was a short-lived therapeutic craze when everyone drank lime-water. We forget what it was supposed to cure, but it made for longevity.

But the third kind of prescription with a smack of reasonableness is even more interesting. Dried toads and ashes of toads have been used medicinally since the time of Aristotle, and it is striking to learn that the alkaloid phrynin, abundant in the skin glands of the toad, causes, when injected, contraction of the arterioles, rise of blood-pressure, increased heart-beat, and so on, which might have a good effect in cases of dropsy due to heart affection. Personally, we do not know, but the prescription seems on a higher plane than that which recommends eating a lizard to cure leprosy.

A fine illustration may be found in connection with snake-bite. The venom is a toxic protein, produced by the salivary glands—a good instance of Nature's way of making an apparently new thing out of what is really very old. (*a*) Now, the natives of various warm countries have been in the habit of drinking diluted snake-poison to render themselves immune; and this is surely in line with the modern recommendations of the late Sir Thomas Fraser of Edinburgh and Dr. Calmette of Paris that an anti-toxin serum, prepared from animals into which small doses of snake-poison have been injected, should be utilised for patients suffering from snake-bite. (*b*) In many of the indigenous snake-bite remedies, the bile of the snake is an important constituent, and it has been shown by Fraser and Phisalix that the snake's (e.g. the adder's) bile is an antidote to its own poison. (*c*) An old Indian remedy is to chew the root of tulsi, a much-esteemed labiate plant, and the value of such treatment is confirmed by the work of Phisalix and others, showing that vegetable tyrosin from the dahlia root acts like animal cholesterin in the bile as a counteractive to the poisonous toxin of the snake's salivary juice.

Another illustration of old animal prescriptions with a kernel of truth may be found in those which recommended the coward to eat the raw heart of a lion, the lethargic to dine on the brains of a ram, and the jaundiced to try the liver of a fox. We smile at these suggestions; but surely they point in the direction of the modern treatment of those unfortunate subjects whose thyroid glands have gone out of gear, with the result that goitre or myxœdema ensues, for they are ordered to eat the thyroids of sheep and calf, or are treated with doses of thyroid extract. Perhaps the old physicians were not such fools as they sometimes seemed. Some of their queer mixtures or philtres suggest that they may have had some adumbration of the extraordinary potency of what we call the glands of internal secretion.

THE STORY OF BILHARZIA.—We can find no finer example of zoology helping medicine than Dr. Leiper's working out of the life-

history of the formidable worm called Bilharzia, common in Egypt and some other warm countries. The discoverer has done great service to humanity, and has brought great credit to the Medical School of Glasgow, where he was educated. For it is probably true that if the student Leiper had not there learned and appreciated the life history of the common liver-fluke, Major Leiper would not have discovered the life history of bilharzia. It is a remarkable fluke or trematode, peculiar in many ways, e.g. in having the sexes separate instead of combined, an elongated instead of a leaf-like shape, and a power of entering man's body through the skin. There are two common species—one preferring the intestinal region, the other the renal region in man, and differing in small details. The great pain which they cause is largely due to the sharp edges of the microscopic eggs cutting into the walls of the blood-vessels and the like. Much energy had been given to the search for the early stages of bilharzia; but it was Dr. Leiper who demonstrated, during the war, that the young stages lived for a while in freshwater snails (like those of the liver-fluke), and that the slender fork-tailed cercariæ swim in the water and enter the skin of some host, such as man, through lesions in the skin. We immediately understand why every third child in Cairo used to be infected with bilharzia (for children are fond of wading), why washerwomen and those who water the gardens are much infected, and why our soldiers were attacked after bathing. But Dr. Leiper did much more than remove obscurities—though this is the first end of science—he showed how the disease could be controlled. Thus the microscopic cercariæ cannot live for more than thirty-six hours in drawn water that is kept quite still.

HOOK-WORM AND GUINEA-WORM.—It is probably true that one of the four biggest and heaviest clouds of disease that have rested on the human race is that due to hook-worm—a name given to several kinds of intestinal nematodes. They cause anæmia, weakness, lethargy, and despair—the "tropical depression" often deplored by missionaries, colonists, and explorers. But now that we know most of the story of this contemptible little worm—how the eggs pass from man to the soil, how they develop there into sheathed and unsheathed larvæ, how they bore into man through the skin—there is every prospect of the cloud being dispelled; and the splendid work done in many parts of the world by the Rockefeller Institute shows how much may be done in a short time. A recent discovery indicates how the parasites can be expelled from man's body when Æsculapius lifts his wand; the rest of the business presents no *theoretical* difficulties—it means persuading the natives that certain simple sanitary measures, such as the use of latrines, are life-saving. Then the cloud will entirely lift. Meanwhile the use of boots saves a large percentage of children from infection.

Take another illustration which shows how zoological understanding may count. For thousands of years there has been some knowledge of the guinea-worm, the female of which lies coiled, one to six feet in length, below the human skin, and produces abscesses and ugly sores. The male usually remains hidden. This guinea-worm was probably the Fiery Serpent that bit the children of Israel trekking in the desert. It enters man, as Major Liston showed, through drinking water containing a Cyclops—a common water-flea, which harbours the juvenile stages. But our point at present concerns its exit. It used to be coaxed out by winding it patiently round a strip of wood, turned a little day after day. Perhaps Moses' coiling serpent was not simply a symbol of hope, but a diagrammatic object-lesson of treatment for his afflicted people. For as one "learned in all the wisdom of the Egyptians", he must have studied medicine in course of this, as indeed the Mosaic Law shows at various points. Nowadays, however, the patient sits for hours with his leg or arm in water, and the long female comes out of herself. The modern method follows from an understanding of the zoological fact that the mature female should emerge from the host to lay eggs in the water. The needed preventive treatment is to take care of the outside of the water-vessel, to cleanse the well from time to time, and to keep a good parapet round it; all to abate the otherwise constant introduction of eggs for the Cyclops to swallow.

PROTOZOOLOGY.—One of the characteristic features in the twentieth-century zoology and medicine has been the development of protozoology. Its origins go far back, but in the last quarter of a century it has grown with such rapidity that outside the ranks of the experts few are keeping in pace with its details. It has its laboratories and professors and journals; and of the two first, at least, we need more. What exactly is the change? It is the discovery that many microscopic animals are just as important as many of the bacteria. Thus, it is well known that Protozoa are responsible for malaria and sleeping sickness; and it is perhaps more impressive not to continue the list, as we might.

Speaking of microbes leads one to think of phagocytes—our natural bodyguard of amœboid cells—and it must be remembered that Metchnikoff was first of all a zoologist. This is discussed under Phagocytosis, but we wish to make the point that the early chapters in the history of the doctrine of phagocytosis were zoological, beginning as far back as 1862, when Haeckel observed that minute grains of indigo injected into the mollusc Thetys were engulfed by amœboid cells.

MEDICAL ENTOMOLOGY.—We cannot think of the development of protozoology without recognising the correlated development of medical entomology; for there has been great insight into the part played by some insects, and likewise some ticks and mites, as

vehicles of disease organisms. Precise zoology has confirmed what many a peasant said long ago, "Many mosquitoes, much malaria." It is well known that infected mosquitoes infect man from their salivary glands, that asexual multiplication then occurs, and that subsequent sexual stages are sucked up by another mosquito, in which the complicated life-history is completed. The whole story of the investigation is a good instance of team-work, but there are some incidents that stand out dramatically. Thus, one likes to think of the two English physicians, Sambon and Low, living for the three worst months of the year in a hot-bed of malaria in the Campagna, moving about freely during the day, exposed to all sorts of weather, drinking marsh water, sleeping in marsh air, taking no precaution save that they retired in the evening to a mosquito-proof hut. As everyone could now predict, they did not take malaria. Another fine incident was importing from Italy into England several mosquitoes which had bitten malarial patients; two volunteers—one of them Sir Patrick Manson's son—allowed themselves to be bitten, and contracted typical malaria. Of great interest is Dr. James Ritchie's investigation of the hospital records in various towns in the North of Scotland, which show that ague or malaria was once so seriously rife that it made harvesting difficult. The Dapple-Wing mosquito, *Anopheles maculipennis*, still lingers in some parts of Britain, but it no longer carries or distributes the malaria organism. The disease became rarer as the art of medicine advanced; the appropriate "carrier", the Dapple-Wing, became rarer as the art of agriculture (including drainage) extended; the present situation is that though the Dapple-Wing is not uncommon in some parts of the country, it no longer carries the Plasmodium, though opportunities for this have increased by the occasional presence of malarial patients in the country. Yet, even after the war, there has been no known endemic case of recent years. Another interesting point is that the paraffin-film method of killing off mosquito larvæ depends on a zoological understanding of how the larvæ breathe. The air-tubes or tracheæ lead to a respiratory trumpet at the posterior end of the body; this is exposed and expanded on the surface film; but if the film is oily, the tail will not grip, and the larvæ drown.

THE WEB OF LIFE ILLUSTRATED ONCE MORE.—What we have said in regard to malaria and mosquitoes, bilharzia and guinea-worm, may be resumed under a more general idea that the zoological recognition of the web of life or the inter-relations of living creatures has proved itself of value in medicine. How are mosquito larvæ to be killed off in Indian water-reservoirs where the paraffin film method is inapplicable? By introducing certain kinds of small fishes called "Millions", which eat up the larvæ. The little Californian Gambusia is now clearing up Southern France.

The microbe of the plague is at home in the rat, and naturally in the rat-flea. When a well-infected rat-flea leaves a dead rat and with its fouled mouth-parts bites man, the plague bacillus continues on its dread journey. But the more cats, the fewer rats, the fewer rat-fleas, and the less plague. It is said that the plague often begins in a mill, in the yard of which there are rats, attracted by the crumbs left by the simple dinners. Hence the commonsense preventive suggested, that if there were a dove-cot in the yard, the pigeons would dispose of the crumbs, the rats would not be there, the workers would not be bitten by fleas, and the plague would slumber. The extensive keeping and feeding of pigeons and other birds—even to peacocks in vast numbers in some places—in Indian cities has thus its reward in public health.

HEREDITY AND MEDICINE.—In the time of Charles I there was a Frenchman called Jean Nougaret, who suffered from an eye defect known as night-blindness, implying an inability to see in dim light. Now, the lineage of the family has been carefully kept since the seventeenth century, and we know that the peculiarity has cropped up in every generation in a certain number of the members. The peculiarity is a "unit character", either there or not there, not blending or fractionating, exhibiting Mendelian inheritance. If a member of the family who was normal married an outsider who was normal, none of their progeny were night-blind. But if an affected member married a normal outsider, the peculiarity cropped up in a certain proportion of the progeny.

Many instances of unit characters are known in man which illustrate Mendelian inheritance—the colour of the eye, the crinkliness of the hair, having "fingers all thumbs", "congenital cataract", and so on; and it is not too much to say that the attitude of medical science to the problems of heredity and disease has been profoundly influenced by recent zoological studies on the organic relation between successive generations.

NURTURE AND MEDICINE.—Of great interest also to medicine are the zoological facts in regard to the potency of nurture. (*a*) Tadpoles fed on minced thyroid gland go on developing, but stop growing. They become differentiated dwarfs; but those fed on a thymus preparation grow without much differentiation. (*b*) White rats exercised for 90–180 days (which would correspond to many years in man's life), showed an increase in weight by about 20 per cent. as compared with non-exercised rats similarly fed; even the brain shows an average increase of about 4 per cent.—a fact for the consideration of athletic clubs. (*c*) If the newt Proteus remains in the darkness of the caves it develops no pigment, and its eye is a mere vanishing point; if it be kept in the light it puts on dark pigment; if the larva be reared under red light, its eye enlarges and shows some differentiation. These are just three straws which indicate

how the wind has been blowing. The medical importance of the study of "nurture"—alimentary, functional, and environmental—is obvious.

HINTS FROM ZOOLOGY.—We have seen that zoology has made stable contributions without which medical science would not stand as it does to-day. But there are scores of investigations which do not at present offer more than hints. Thus, to begin at the beginning of life, it seems unlikely that there is not some medical application for the facts of artificial parthenogenesis or aspermic development. The researches of Delage, Loeb, Bataillon, and others, have shown that it is possible in a variety of ways to set an egg-cell developing without its being fertilised; and that if this artificial start is speedily steadied by replacement in normal conditions, a quite normal development may result. This has been effected in many cases, in sea-urchin, in sea-worm, in mollusc, and as high up as frog. The sea-urchin ovum may be activated by dilute butyric acid or by a mixture of tannin and ammonia; the frog ovum may be activated by pricking with a needle, and a subsequent douche of blood. Now, suppose we could correlate this artificial stimulation of ovum development with the strange growth of galls which follows physiological stimulus from the salivary secretion of the larval gall insect, and with the stimulus that induces the regeneration of a lost part—a starfish's arm, a lizard's tail—we might *perhaps* get some indirect light on an obscure problem like that of certain abnormal (teratomatous) growths in Man.

Or to go to the other end of life, a great deal of zoological work has been done on the normal ageing or senescence of animals. Everything points to the conclusion that what really ages is the fine colloidal framework of the cells; not the living matter so much as the furnishings of the cellular laboratory. In simple animals, up to planarian worms, the length of life's tether seems indefinitely long, for processes of rejuvenescence are continually counteracting those of senescence. Should there not be more serious and ambitious study of man's possibilities in the way of rejuvenescence?

The busy bee was one of the exemplars of our childhood. It certainly improves each shining hour, but with an excess of zeal which seemed to us very fatuous, and we were right; for the shining hour does not improve the busy bee. It grows old rapidly, and has a very short life. Its brain-cells go quickly out of gear; their microscopical examination shows the effects of nerve tiredness at the end of a busy day, and the effects of nerve fatigue at the end of a midsummer month. As Professor Hodge says: "The nerve-cells, in the course of the bee's daily work, gradually cease to be functional, and die off until no more are left than are sufficient for the necessary vital functions." Hodge's work on the bee suggests that there are three grades of nervous "wear and tear": (1) There is normal

daily tiredness, from which more or less complete recuperation is provided by rest (including meals); (2) there is "fag", from which recuperation is difficult, but possible; and (3) there is a fatal fatigue when the over-worked cell collapses. The story of the bee's brain, confirmed by Smallwood and by Mrs. Goodrich, is a warning not so much against over-industry, as against over-specialised industry and too long hours. It is a warning against being over-busy—a warning much needed by most men in North Temperate countries who have very little of the resting *instinct*. This may be remedied by a cultivation of the resting *habit*, in which connection it must be emphasised that for young people the greater part of rest—outside of sleep—should be a change of activity.

Take another illustration of what one might venture to call *prophetic* researches. There is an old problem like the origin of evil, the problem of monsters. What is the cause of such ugly things as creatures with one eye instead of two, or no eye at all, or one ear, and so forth? There are several answers, such as the idea that deficient nutrition at critical stages may cause "arrests of development", as in hare-lip. But another kind of theory is suggested by Dr. E. L. Werber's experiments on the American minnow. He subjected the developing eggs to various re-agents, notably butyric acid, and he got all sorts of strange monstrosities in eyes and ears, nostrils and mouth, head and fins. The chemical intrusion seems to dislocate and partially dissolve the essential germinal material, especially at the head-end. Hence monstrosities. But the question arises how any respectable embryo in natural conditions could possibly be influenced by anything at all like butyric acid. The answer is that if something goes wrong with the carbohydrate metabolism in the body, there may be a production of substances not very remote from butyric acid; and if the *mammalian* mother's constitution were thus poisoned, this might well cause monstrosities in that mother's child. Thus, we have a zoological contribution towards the mystery of monsters.

Then there is the biggest fact of all that there is in wild nature practically no constitutional disease among animals, and practically no senility—a fact which medicine has not fully faced.

But let us end on a lighter note. Long ago there arose in China or Japan a mutation called the dancing mouse, and a hint of it occurs occasionally among wild mice. The animal breeds true, and is a fascinating bundle of peculiarities. It is quite deaf, except for a day or two in early life; it is given to excessive waltzing. Repeatedly it has been reported that the dancing mouse has only one semicircular canal well developed, that it has something wrong with its cochlea, that it has a peculiarity in the auditory centre of the brain, and so on, but further investigation seems to have shown that its ear and brain and other parts are structurally quite normal. It

seems as if there were some physiological peculiarity which affects the animal as a whole. But the greatest of its peculiarities is perhaps that we do not know on what its peculiarities depend; and such a case must surely be very interesting to students of medicine!

Perhaps we have said enough to show why it is urgent to tighten and strengthen—and multiply—the links between natural history and medicine. Yet we must not forget the influence of health or disease on the personality as a whole.

Thus the brevity of Darwin's working-hours, as of other eminent men of letters also, and the dyspeptic and other miseries of so many prolonged workers like Carlyle, and even Huxley, are very probably to be in part explained as indirect consequences of eye-strain; and De Quincey's over-indulgence in laudanum has been ascribed to his finding it thus helpful, without knowing that an oculist might similarly have helped and yet restrained him. And so on for various other limitations or excesses of genius; a better theory at least than Nordau's, of their mental degeneration. So too the fevering of malaria has been offered as medically extenuating the moral excesses of too many Cæsars and other despots; much as its weakening results explain the submissiveness which too tamely tolerated these.

The victory at Waterloo—as a no less irreproachably patriotic historian than Field-Marshal Sir Garnet Wolseley has pointed out—was not a little aided by Napoleon being so long out of action in agony during a critical period of the battle; and a recent German medical writer has insisted on the arterio-sclerosis of Von Kluck, and of other of his leading generals too, as a noteworthy element in his defeat upon the Marne; since for these a real disability in conflict with the healthier and quicker-witted leaders on the French side. Here, in short, is a fresh and fertile line for medically minded historians and biographers; and we cannot but agree that it works well the other way also; for must we not bear in mind the magnificent all-round health of Goethe in discussing his varied and long continued life-achievement?

NATURAL SCIENCE AND MEDICINE

It is a now very old and thoroughly familiar story, manifest in every history of medicine, every retrospect of botany and zoology, as well as of physiological and morphological inquiry, that these have often and notably interacted; and particularly from the medical side. And this not merely because the most devoted of naturalists have till lately had little or no other means of earning a living, and this even in travel, or in medical schools, but also because the needs of action are ever stimulant to thought and

inquiry, and this surely nowhere more vividly than in dealing with the sufferings and dangers of life. Aristotle's interest, observation, and insight in biology owed much to his medical parentage: and the botanical classic of his disciple Theophrastus too; while from later times to comparatively recent ones, as from Dioscorides to wellnigh all before Linnæus, and sometimes since, medical influence has not been lacking. Thus for eminent botanists and zoologists in our own country, enough to recall the names of Robert Brown, Hooker, and Huxley, to see them as doctors out on exploration, and even Darwin's Edinburgh beginnings of research as in fruitful truancy from its School of Medicine.

Again, take our modern biological insistence on Life as fundamentally the interaction of Organism with Environment, as outlined further in another chapter, and with each thus needing not only analysis, but correlation in detail. Both attempts are at least as old as Hippocrates; witness his conception of our organismal life as presenting various temperaments—sanguine, nervous, lymphatic, and bilious or melancholic types of constitution; and on the other hand his insistence on the importance of environment both in general and particular, in his *Air, Water, and Places*. And without going too far into medical history, it is here well to recall that his teaching is no mere old story, as presented in most schools of medicine: it has been the very life of that of Montpellier, as at once the earliest school after Salerno, and as keeping Hippocrates at his best as leader of its method, doctrine, and unbroken central teaching—whence for England even Sydenham himself—that doctrine of Vitalism, which—despite its inevitably too general and abstract expression, pending the modern research it has so largely initiated and aided—is being vividly recalled and re-stated at the current meeting of the French Medical Association in that very School of Medicine as these pages are being written; as well as in the growing movement of the neo-Vitalism now arising in all countries. This does not, of course, under-value, much less reject the often invaluable contributions of the biomechanist, biophysicist and biochemist—each a welcome part of the legitimate materialism of physical science as underlying the biological; but none the less correcting the error too easy from such approach and perspective, that of the "illegitimate materialism" of imagining that we have thereby reached the essential secret of biology itself. The neo-Vitalist has thus but to supplement these labours (yet utilise their example of thoroughness and accuracy) by making the essential Biodrama more clear, i.e. the view of living beings in their self-maintaining and species-continuing activities. And these as essentially directive and co-ordinative of functioning and forming; and furthermore, as increasingly associated and interactive, throughout organic evolution, from its incipience to its completeness, with biopsychosis and

psychobiosis, in short, with psychic evolution as well. Hence, in fact, our main general view of evolution is from Protista and Protozoa towards Psychozoa; so from Pro-Anthropos through *Homo ignorans* to *Homo sapiens*, and with *Homo sapientior* as his latent and potential Super-man. So also beyond reptilian and lower or higher individual struggle for existence, and increasingly towards the culture of existence; and this idealised, even to that of Parnassolympians in Eutopia, or whatever fuller and higher conceptions we may attain.

That the teaching of the biological sciences as preliminary to medicine still falls far short of its requirements, our own long lives of such teaching endeavours have taught us to realise. Our comparative anatomy and morphology, classification, palæontology, and so on, have been more interesting to us as naturalists, than to our medical students; and could we begin again, we should seek to be more physiologically interpretative than ever. They naturally are more interested when we speak of bacteria and germ-theory, or of main physiological processes, self-maintaining and species-continuing in ecology, in development, and in evolution. And with freer conditions, we should give less time to structural comparisons, and more to the functional interpretation of structure: whence to the more physiologically rationalised study of forms and their development, of ecology and evolution. And all this from (say) Bacteria and Germ-theory onwards to Life-theory, organismal-environmental, as from Hippocrates to Pasteur and back again. We should thus be teaching from the advances of biology; yet also in touch with the continual advances of medicine; and thus better advancing its introductory teaching as well. Beginning, however, with the former, let us take an example or two. To the botanist, it is particularly obvious that the anatomist's customary analysis of the organism, at once into its component organs, is premature and unsatisfactory; since, in its conspicuously dual vegetative and reproductive systems, each has its own functionings, and its organs accordingly; the root, stem, and leaf on the one side, and the essential reproductive and accessory organs on the other. The true first analysis of the plant is plainly into its two distinct Life-Systems primarily; and so it is in animals. But in specialising on the organs of the self-maintaining life, and leaving the consideration of the species-continuing system, with its organs and functions to the last (if not even omitting it altogether, as in Huxley's otherwise excellent *Elementary Physiology*, so long a standard text-book), and much the like even in many of the later and larger manuals, our whole presentment of biology is thrown out of perspective, and indeed into a wrong one; which the vast amount of sound and serviceable information on respiratory, circulatory, nutritive, and neuro-cerebral structures and functionings, etc., conceals from

writers, teachers, and students alike. Weismann was here on the right track—though at the deeper levels of analysis, cellular and protoplasmic—in his germ-plasm theory, with its important consequences: and for a like appreciation of the supreme importance for good or ill of reproductive urges and functionings, even for the self-maintaining life itself, we have the immense Freudian movement; yet this essentially from the psychological side, and that approached from the pathological expression—albeit increasingly getting beyond this, and even to the interpretation of the sublimation of reproductive and sex impulses towards individuality at its highest, as in poetic and other developments of genius.

Yet with due appreciation of all this, we cannot but also claim consideration for our own line of approach and treatment of these subjects here—as from the general survey of normal plant, animal, and human types in their dual life, and thus very definitely in their evolution of reproduction and sex; to which the self-sustaining life, despite its ecologic interest and economic importance, is in every species sooner or later subordinated—yet also individualised by this, as a plant by its flower; and to the corresponding developments in animal and human normality, towards beauty and perfection; and this in form, in functioning, and in psychic life accordingly; in short, through its ascending evolution of the sexes. Hence as brief example of this treatment, the preceding outline indications and illustrative examples of the process of floral evolution in the natural orders of plants; which might next have been traced in many lines of animal life, and similarly in humanity.

Thus in the descending analysis of the organic individual, even the classic "temperaments" of Hippocrates—still plainly continued in those fuller studies of "constitution" and "diathesis" which in medicine ever bulk so largely—must yet be developed beyond their usually too simple treatment, as mainly characteristic of the self-maintaining life, and more fully interpreted by help of the reproductive life also; as again so notably in progress, from the psychologic side, by the Freudian schools. In summary, then, we press for the ever fuller consideration (and by the psychologist as far as possible along with the physiologist), of the evolutionary importance of the oscillating balance of these two main elements of life's activity, the self-maintaining and the species-continuing.

For their mutual modifications, and their differing co-adjustments—and these each by turns with biopsychoses and psychobioses, of progressive or degenerative results—are surely significant—and does it not seem often determinative—of the process of evolution in the origin of varieties, species, and more. If so, this view deserves more consideration than it has yet obtained.

THE CELL-CYCLE

Continuing our descending analysis, from vegetative and reproductive systems and organs, through tissues to their cellular life, we cannot but regret that the fruitful and intensive microscopic observations of wellnigh three generations since Schleiden, Schwann, and other contributors to the establishment of the cell-theory—and despite the physiological and pathological insight of Goodsir, Virchow, and others—have as yet remained too simply morphological; though in that respect of ever increasing interest—witness our new intensive knowledge of cell-structure and division, and even of nuclear chromosomes and genes as well. Yet with all the interest of these phenomena, as even of the genes for heredity, we still lack explanation of their working; in short, we have still too little of physiological interpretation. Hence we cannot but plead for more consideration of the simple doctrine which underlies not only our "Evolution of Sex", "Sex", and "Evolution", but is increasingly a general conception for evolution—that of the cell not simply as subject for structural analysis, but as more or less presenting, as a whole, and in its development and changes, physiological, and thus morphological, a cell-cycle. That is, a potentiality and frequent manifestation of cyclic changes, of functioning and form accordingly; and these intelligible in physiological terms, as associated with its varying metabolism. For when the constructive and anabolic side of this ultimate and dual chemical and physical life-process of all living bodies, small or great, simple or compound, predominates, we have growth, with relative passivity, and tendency to spheric form. Whereas, when destructive and katabolic activities predominate, there must be reduction in bulk from wear and waste, yet with liberation of kinetic energies, even to movements, and these at very various levels of intensity, as from simplest Amœba to most active infusorian or monad. On the reproductive side too, the contrast is carried to its extreme, in the passive and often large and well-stored ovum, and the minute, but long sustainedly active, spermatozoon. The main forms of Protozoa, and even of Protophytes, thus also range from encysted and long enduring passivity to moderate or intense mobility on emergence, witness the startled surprise of the first discoverer of this striking phenomenon, recorded in the title of his paper, *The Plant in the Moment of Becoming an Animal*.

This alternation of growth to maximum, followed by a period of rest, yet renewing to activity, is widely characteristic; first of the Protozoa in their development, so that even the apparently lifelong encystment and passivity of the parasitic Gregarines is preceded by a brief yet distinct motile phase, while conversely the

apparently permanent activity of infusorians has often also its resting phase. It is thus no wonder that we find the like alternation continued in the characteristic sex-cells of the cryptogams; and even with traceable continuity in those yet more cryptic super-cryptogams, the flowering plants, which deceived botanists in calling them "evident-flowering" and thus Phanerogams, though really the very opposite. The importance of heredity through sex-cells especially, has also too much and long eclipsed the associated contrast in the vegetative life; for (as pointed out already) this

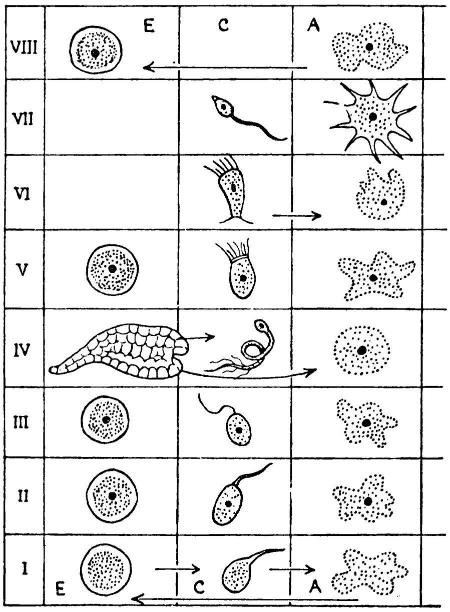


FIG. 196.

Diagram Illustrating the Cell-cycle. E, predominantly encysted; C, ciliated or flagellate; A, amœboid. I, II, and III, in Protozoa; IV, ovum and sperm-cell of fern prothallium; V, three animal cells—encysted, ciliated, and amœboid; VI, ciliated animal cell pathologically becoming amœboid; VII, typical sperm and amœboid sperm as in many crustaceans; VIII, amœboid ovum as in Hydra and encysted ripe ovum.

also has its more growing and feminoid individuals, varieties, species, and more; and these in contrast to correspondingly more katabolic and masculoid variations. This contrast of anabolic passivity in growth with activity relatively more katabolic, is again traceable throughout orders, classes, and phyla, and obviously underlies the main division, of Vegetabilia and Animalia. Yet these were rightly united by Linnæus, in truly biologic spirit, as Organisata; and still, despite all their vast differences, expressing their origin from Protistan forms not clearly classifiable as plants or animals, since presenting, in their cell-cycle, the main characteristics of both.

Given this cell-cycle, have we not here a clue towards inter-

preting the differentiation of tissues, more active or more passive; as from the actively ciliated cells so common in lower types, and even lining usefully our own wind-pipes, to the more or less actively contractile cells of muscle tissues, so different in efficiency and power in various phyla, to the passive and encysted cells of cartilage, and their even calcified encystment in bone. Even the amœboid type—in various comparatively slight, but physiologically important differentiations—persists in the leucocytes of perivisceral, circulatory, and lymphatic fluids, so familiar throughout the animal kingdom, up to ourselves. And even in the elongated growth and ramifications of developing nerve-cells, despite their supreme physiological complexity, do we not see likeness to the development of rhizopod-like pseudopodia? Many embryonic animal forms show more or less of this cell-cycle in the early phases of their development. And the like too in pathological processes. The ciliated cells of the outer epidermic layer covering a planarian worm, when exposed to cold, may relapse to unmistakably amœboid form; and may we not suspect that the too frequent indisposition of those of our own air-tube may be so far in like manner affected? And as leucocytes may leave the circulation to settle down into passive cells of connective tissue, are they not thereby exhibiting something of the ancestral cell-cycle? And since such connective tissues may resume growth and even show active cell-division, and thus attain to passive tumours—which also may become active in their parent organism—may we not interpret at least one factor in such disease as of reversion to something of the ancestral cell-cycle; yet this interfered with by their surrounding conditions, and these pathologically exciting to and by it. That disease is associated with disturbance of that general co-ordination of the organism which is health, and that the re-establishment of co-ordination is the explanation of the *vis medicatrix naturæ*, are old and familiar ideas in medicine; yet the above conception of the cell-cycle may at least have suggestiveness, and towards other interchanges of biological and medical ideas.

BIOLOGY AND MEDICINE AGAIN

The fact is that each profession, each line of occupation, and indeed each age and sex also, has its own familiar and customary thought-world, and does not easily get beyond it, nor readily welcome and incorporate contributions from others. Thus neither the religious, the political, the administrative or legal training has much contact with even the physical sciences; while the industrial occupations rarely go beyond these. So biology has been as yet mainly left to the education of the medical profession; but its members are generally too young to master its principles as students, and too

busy as practitioners to keep up with its advances. As to the social sciences, these have still the greatest difficulty in getting a hearing at all; save as regards history for church and law, and economics for the industrial world; and neither of these in adequately sociological form. The various social evils indeed cry out to all the professions; yet they are only beginning to obtain scientific treatment; as notably public ill-health, and mental troubles, from wide-minded medical leaders; while most even of these have difficulty in getting further, to enter on those fuller studies of cities and their regions, with their occupations and population conditions, which afford the best concrete introductions to social science.

Hence the more integrated education, which opens windows and doors to Nature and to Civilisation, is still but in its beginnings; and to accelerate this advance in concrete details on one hand, and to broad general outline on the other—and on all levels, primary, secondary and higher and, of course for both sexes, as well as all occupations and professions, from simplest to highest, is urgently needed; alike to abate present evils, difficulties and conflicts, and to advance progress of all kinds.

Since as social beings we are ever interacting with our environment, and thus mainly in its immediate circles of home and friends, of neighbours in region and city, with their familiar range of ideas, our normal laughter is mainly on these simpler life-levels, which all can widely share, as in childhood and growth, to adolescence, and to love. Hence too it is that the more developed and individualised humour of different cities, regions, peoples, and tongues, is not easily or always translatable, save where it ranges to keenest or deepest, and thus anew widens its appeal. As again that of times of social transition; yet even of Aristophanes or Rabelais, of Erasmus and More, how much now is lost, or all but irrecoverable? Of vulgarised laughter, however contagious—that of mere giggle in gabble, in gobble or guzzle—we need not here speak, though Rabelais and others have often hid their deeper humour under it. So here again must we not return to the ever-pioneering Bergson, with his keen and detached insight, reinforced by his vision of evolution beyond our mechanical age and its correspondingly prosaic thought, and towards life more abundant, more free and varied, more happy and joyous accordingly. Yet combative, too: for such life in its evolution has no easy task for survival, no small difficulty of extrication from our mechanised Industrial Age, and into that opening Life-evolutionary phase, which we may thus claim, and hail, as the Revivance. Here then is the paramount value and significance of Bergson's humour—his vision of richer humour and fuller laughter opening before us, on one side of ridicule of every subordination of life to mechanism, and on the other of joy, as life anew emerges to mastery.

BIOLOGY AND MEDICINE; WHAT COMMON POLICY?—Politics? No; for though schools of law and economics, if not even history, are more than ever frizzling in politics, and University Unions voice and train for it, the student of medicine or its associated sciences, remains mostly immune to its fever. Usually, he thinks, because too busy, or as they think, too individualistic; but really because he "does not dance that dance"—since neither abstract eloquences nor forensic debate, be these of nationalistic or mechanistic, financial or proletarian type, as yet appreciably come to touch biologic and medical thought, or their applications. If and when the biologist or the physician looks into the arena of politics, does not that seem too much a debate of barristers unemployed or amateur, rather than that observant survey, interpretative diagnosis, and cautiously experimental treatment, as of evils towards their abatement and prevention, which the medical mind is more directly engaged with. Yet in his attention to the pains and dangers of individual life, the busy physician gains many social impressions, with ideas and larger purposes accordingly. Among these, hygiene has long been in development, and now seems fairly sure with the opening generation; and eugenics, with its vigorous appeals, also looks forward for fuller medical and social consideration.

Why is progress thus so slow in the social levels, so that cities are still so unwholesome and under-housed, country villages so often proportionally yet worse off, as compared with what they should and so easily might be? The wheels of politics seldom fit and move ours, nor as yet conversely. What intermediate agency is needed, beyond the occasional "crank", more useful than he gets credit for? One answer, at least, is surely—Citizenship. Thus so representative a medical city as Edinburgh has had, though only once in its history, so far as we know, a biologically-minded physician and hygienist for its Lord Provost, so with a record clearing-up of some of its slums accordingly, on sound lines of conservative surgery still too uncommon; and lately, at Aberdeen, a vigorous citizen in that high office became aroused to the need of renewed hospital development; with speedy and large result, indeed a record, many times beyond the not inconsiderable hospital generosities of London. Private agencies, uniting the endeavours of hygiene and citizenship, have also done much, and may before long do more. Here, too, it is not a little encouraging to cite the little story of Lord Dawson, the senior physician of the King during his long illness in 1929, who, when congratulated on his success and that of his colleagues, but with the additional remark of "what a pity so few patients could have such advantages"—replied that they and he were proud to be able to say that the King, though necessarily treated in his own house, had been as well taken care of, and with team-work, etc., as if he had been a patient in a good hospital!

Another answer is Education. For some of its present notable advances, e.g. Dr. Montessori's pioneering and that of Dr. Adler and others, are examples of the fruitful intercrossings of medical and educational psychology. One way to this—one to which, after lifelong teachings and ponderings, we only feel adequately awakening as we write, and as we are dropping our oars to look around and forward—is that, despite all the many needs of improving medical education and remedying its defects, as from over-pressure to under-experience, most of these may best be met by developing its qualities, in many ways so far ahead of the instruction and preparation given in the other old faculties and departments, of letters, law, or divinity. Thus, though the medical student has usually done with letters when he begins his course, more than in most other professions, he keeps touch with the advances recorded in other languages. He gets into touch also with law, through medical jurisprudence, and with history through that of medicine; while from the first beginnings of practice, he is learning much of the human kindness of the good parson, and even of the confessional of the wise priest; and as seeking to turn his patient to better habits, he becomes something of educationalist as well. Even his first year's preliminary studies are more significant for education than in his natural impatience to get to work he commonly realises; for his outlines of physical and chemical science on one hand, and of biological science on the other, are what all other schools, and University faculties also, require far more than they yet realise, amid their present seas of words. For—first of all in the laboratories of each and all these preliminary studies, as in those of later ones—the medical student is taken out of the feebly verbalistic instruction of the three R's, with their "parrot's training", their memory examinations. He is getting a start of real and occupational education, through eyes and hands to head, and with practical examinations as tests of working competence accordingly. Is not all education in need of the like? He is thus so far practically prepared for that fuller awaking of youth which so often comes to him with his first bit of real medical or surgical responsibility, as from the sudden accident of cut or burn, of bruise or fracture, of syncope or seeming poisoning. After that arousal, he often feels his work has really begun, and sees more fully the need of further studies for it, and along with it. Furthermore, these first year science studies are anticipating for the student the needed and incipient progress of our social world. For while we need to understand all we can of the physical fundamentals, by which our industrial age has been brought about, with its qualities and its defects, the needed advances beyond its limitations are not those for which the other faculties prepare, as with more politics and bureaucracy, more preaching or more print; but quite definitely, that advance towards the understanding of life for which biological

studies and labours are the right introduction, albeit still too imperfectly developed. If so, are we not renewing the claim for education, beyond most current demands, or even these of most of its special pioneers?—that for "des clartés de tout" made for women by Molière, after all his ridicule of their acceptance of academic pedantries, now too often being repeated by them in our universities. Here, in this too brief initiation of the medical student, is in principle the granting of the claim of Comte for mathematico-physical preliminary instruction, followed by more fully bio-psycho-social education; and so well reinforced in Herbert Spencer's best known master-work, his *Education*; though its needed sequel, *The Study of Sociology*, still too much awaits its turn. Yet groups like the Medico-Sociological Societies now forming must surely before long take that fuller action towards this, of which the beginnings come down to them, all the way from the oath of Hippocrates. In our outlined discussion of Life's Evils, we have noted that though philanthropists and pedagogues, priesthoods and police have long been dealing with the special evils of poverty, ignorance, vice, and crime respectively, it is with the work and influence of the psychological physician that the more unified treatment of these evils is making most progress; and from which all these too separate workers are being influenced towards kindred breadth of outlook, and associated endeavour. If so, here is surely a fresh impulse to medico-social education; and for its needed vacation-courses, and meetings, to which each and all may bring their contribution, and towards fuller co-adjustment of it.

The individual line of such bio-medical advance—that of training the patient to return to life with better habits and activities and outlook has been long used by psychological physicians; and it is stated with fresh practicality in Dr. Brock's *Health and Conduct*—since here associated on the educational principle of the 3 H's, heart, hand, and head, from and to fresh interests through nature and occupational activities, to normal life on saner and sounder levels than before. Such psycho-biological and even psycho-biotechnic physicians are thus learning practically to incorporate the best from the mind-curing groups and sects of recent fame; though they still need more of their socially influencing and organising powers, and of their glowing ardour as well. And these will come with the fuller realisation, by medico-social leaders and pioneers, of their fuller career of social service now opening. For no longer content with mere abatements, medical and hygienic, of the pains and evils of our industrial age, but discerning its essential error and failure, in subordinating life to machinery, the profession of medicine has now to lead that better social period, incipient at so many points, in which machinery and resources, labour, skill, and science are being turned to the service of life, in its development and evolu-

tion, human, social and organic together. Thus more and better than all the Mechano-technic age of applied physical science has accomplished, the incipient Bio-technic age, vitally equipped with bio-psycho-social science, has still to do. The increasing victories of medicine and hygiene as over malaria, hookworm, sleeping-sickness, etc., in the tropical world, are surely each an inspiring earnest that a world-renewal is beginning, and that its continuance is within our powers, since at our doors.

Human Anatomy in Progress to New Applications.—Among all the biological sciences, human anatomy is generally, from the viewpoint of the others, considered the most advanced and settled, indeed the nearest to its limit; and this opinion seems common among anatomists themselves, and also the surgeons and physicians who utilise their extensive and accurate knowledge. It is refreshing, however, to hear as to this the different views of a thoughtful and critical minority. Thus to cite Prof. Sir Auckland Geddes, "anatomy is one of the most backward of all the sciences" and "hardly beyond the stage of isolated observations. . . . Not yet has the stage been reached, when from a study of the surface appearances we can tell with tolerable certainty the arrangements and proportion of the hidden parts; and yet towards that end anatomy is striving. An anatomical-pathological-clinical system is needed, with its formula thus—Superficial and visible structural peculiarity A is a mark of internal and invisible structure B; this a type of a bodily organisation D; and this is a mark of, it may be a cause of, a liability to develop morbidity E. From the different types of growth of hair, it is sometimes possible to form an accurate estimate of the efficiency of the supra-renal bodies and of the liver; and from the proportionate length of the limb-bones it is possible to judge the activity of the reproductive glands. The date at which the epiphyses close is conditioned by the state of the reproductive cells; and in later injury in epiphysial regions a surgeon who fails to consider the sexual hair of the face or body may be misled in his diagnosis. A large development of thoracic subcutaneous veins gives warning of liability to tuberculosis". . . . Thus anatomy may "advance from being a pure descriptive science until it becomes an inductive science, which will carry on its shoulders the preventive medicine that deals with man, that strives to develop man's dormant possibilities to the highest pitch, that he may move through this microbe-infested world uninfected and undismayed. . . . As the correlation of structural peculiarities with liabilities becomes more certain, so will the methods of inducing favourable alterations in the structure of the body become more sure".

Comment here is beyond our depth, save to note that reflection is evidently needed, and towards further investigation upon all these deepening levels. Yet also to wonder if there were not already

the beginnings of these far-penetrating inquiries in old Hippocrates' keen scrutiny of "Temperaments" and their significance, in health and in disease? The students of heredity have long been discussing this question, and so are eugenists too.

MEDICINE AS APPLIED BIOLOGY

So much and justly is heard of the strides of medicine in modern times that we are a little apt to forget the extent to which the apparently new is a recovery of lost knowledge. Hippocrates has never ceased to be its historic master; and even Galen—who of all authorities was longest maintained by obscurantism, even against Harvey's discovery of the circulation—is now vindicated by his latest translator and commentator as the very Bergson of his age. A good many years ago the British Museum's decipherer of a Babylonian library faithfully translated one of its medical works, in which he found that "the wasting sickness is communicated by the sputum of the patient". But this had to wait for understanding, until later studies of tuberculosis, and Koch's discovery of its bacillus. How many scores of millions of patients have suffered and died throughout the many centuries between the losing of such clear knowledge and the recovery of it?

Again take a Biblical saying, "the pestilence walketh in darkness". Though doubtless scholarly commentators dissipate this into symbolism, the Jews have from a long past produced physicians second to none; and it, at any rate, seems a strange anticipation of what we are still learning in our own day as to the many bactericidal and other curative values of sunlight. More obviously certain is that while other oriental countries like India to this day keep no cats or but rarely, and thus keep rats and mice (lovers of darkness) in abundance, with consequent visitations of plague from their fleas, the wise Egyptians not only cherished the cat but elevated her to the rank of a goddess, Bubastis, who thus protected them in her turn; while as further confirmation of this, we are told by the Egyptologist that the hieroglyphic symbol for plague is an unmistakably well-sketched rat. So, too, for the keeping of pigeons in India there is obvious bio-medical justification, since they pick up crumbs before the rats come out at night; though Columba is less efficient than Bubastis, since she is nocturnal too.

Modern physicians are thus being reminded of values in past traditions of their art; so among the many rising organisations of medical research, is there not still room for a careful inquiry into these? Thus in India the Hindus and the Moslems have each their distinctively trained physicians, the vaids and the hakims respectively, representing distinct schools of medicine, the

Vaidic and the Unani systems, and with doctrines, drugs, and modes of treatment frequently different, and often anything but convincing to the European mind. Still, their respective percentage of cures is generally reckoned not so far below that of western physicians; though, of course, these remind us, with justice, that they often get the graver cases, and many past hope. Both these old systems admittedly derive from ancient Greece; so here may be promise of light on medical history, as well as suggestions from their apparent successes, as with drugs or decoctions by us still too little known. So, too, the homely practices and experiences of the people in other countries have often yielded invaluable suggestions; thus Jenner was started to vaccination by the village milkmaid. Pasteur's amazingly productive career was developed—as he well knew, even to his dying words—from his origins as a tanner's boy, impressed to reflection by the daily experience of decay prevented by antiseptics; and Lister was not only his disciple, but the living re-embodiment of the old-world "shepherd, with his tar-box by his side". Nor can these be the last cases of this old-knowledge and wisdom of the rustic world, which are lost and forgotten in those often too dark places of the earth whose inhabitants pride themselves on, as the great cities of light.

Most conspicuous among medical centres, vaster than their many hospitals, are the medical resorts; originally mostly for their waters, and often dating from Roman antiquity, like Bath, and three of "Aix" (Aquas) and more; with others more recent, like Vichy and its rivals. High sunny places, like Davos for phthisis, or Leysin for heliotherapy, are again but examples of a numerous class; while even those fundamentally of psychic appeal—which also date from antiquity, though Lourdes has renewed, if not surpassed them—seem also undeniably to have their striking cases of success, as indeed is not unreasonably to be expected. In America too the admirably comprehensive team-work of Battle Creek attracts patients even from Europe for periodic overhaul and repair; and such collective institutes are arising in other countries as well as our own. Particularly suggestive and significant is also the initiative of that eminently wise physician, the late Sir James MacKenzie, as so notably towards the investigation of illness in its earliest stages, of pre-illness indeed, in fact of the very embryology of disease; and so with his Institute at St. Andrews designed with his all-round medical insight, and with exemplary advance in bringing into this the local and regional practitioners, towards scientific co-operation accordingly, and when need be practically as well.

But these centres and institutions, old and new alike, seem not to have attained to such co-ordinate influence and example as the ancient medical centres of Greece. Thus Epidauros, in Argolis—of which the easily accessible descriptions, from any

encyclopedia onwards, need no repetition here—seems alike from its ruins and its traditions to have on the whole surpassed all successors, and this not only in its magnificence and beauty, but in the comprehensiveness of its aims, uniting medical treatment in principle comprehensive, with psycho-therapy no less widely so. Is it not time therefore for great medical schools, so long strictly confined between their teaching and their hospitals, yet now extending their activities into manifold lines of research, to be also taking a fuller part in the separate healing resorts and institutes around them, and helping to raise these not only to more and more of team-work, as now in progress, but also as far as may be, to the rank of an Epidauros; why not indeed laying the foundations of such a health-city of their own? In at least two such medical schools, of long-known and still active eminence, Edinburgh and Montpellier, sporadic initiatives towards something of Epidauros are beginning to feel their way; yet not so rapidly but that any others may take the effective lead. Meantime let us be continuing also the far vaster task of cleansing, from their dirt and grime, their deadly and depressing smoke-pall, our existing cities; likewise sanitating towns, renewing their villages; for when all these are in order and beauty, our existing hospitals, and even health-resorts, should diminish rather than increase. Yet the great difficulties and delays on the way of all this, as sanitarians and town-planners find daily in their practice, show that the prevalent mechanistic-pecuniary culture on one hand, and the traditional literary culture on the other, which between them have as yet crushed the minds of all classes within their too limited moulds, remain alike all but inaccessible to the essential ideas of biology, and so even to those of medicine; as also to those of social science, and its applications, though now becoming civic and regional. Still a new generation is arising, with a larger proportion of minds not thus so fixed, so surely with many opening ones.

At present perhaps most striking of all is the current progress in the treatment of leprosy, which has so long baffled physicians. India, which suffers widely from this, has a very old story, of a maharaja who became a leper, yet was cured by a wise rishi, through his prescription of an oil-containing plant, called Chalmoogra. After modern medicine had so far failed with leprosy, and so could but segregate in Leper Asylums as of old, it occurred to Sir Leonard Rogers—one of the brightest of our often eminent physicians in India, and who has even found a treatment for cholera—to identify this plant, and give it a trial; and behold—with encouraging success, now aided also by the biochemists, who are extracting and combining its active principles. It thus seems that one of the oldest and most abhorrent of diseases is nearing its practical elimination.

The terrible sleeping sickness of Central Africa seems similarly

in way of being overcome; and the recent progress of the treatment of syphilis—first thanks so notably to Ehrlich and Wassermann, and more recently to brilliant workers of the Pasteur Institute—is now being utilised throughout all our cities.

THE SCIENCE OF BIO-SOCIOLOGY

Biology has a large number of facts and ideas which the sociologist, if he is wise, will take account of, and the social reformer, if he is alert, will utilise. Let us think of some of the con-

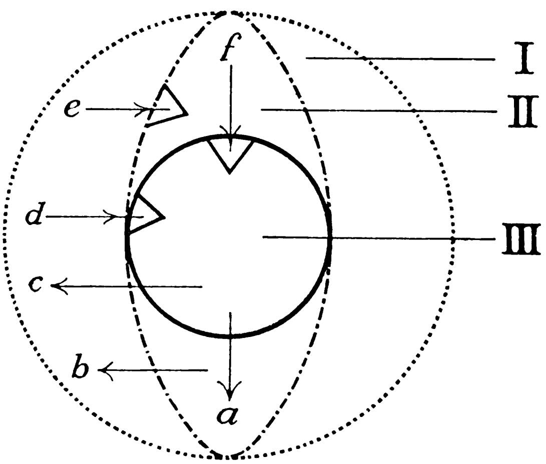


FIG. 197.

The Field of the Sciences. I, The Domain of Things, the Cosmosphere. II, The Realm of Organisms, the Biosphere. III, The Kingdom of Man, the Sociosphere. The arrows indicate influences: (*a*) from III on II; (*b*) from II on I; (*c*) from III on I; (*d*) from I on III; (*e*) from I on II; (*f*) from II on III.

tributions that biology has to make to sociology and to the endeavours of the social reformer. To begin with, let us give attention for a moment to a simple graph, which suggests: (1) the cosmosphere, the world of things, from solar systems to dewdrops; (2) the biosphere, clothing the earth with a thin living envelope, the realm of organisms; and then (3) within that again, the kingdom of man, the sociosphere, the world of human affairs and institutions.

It is a very elementary graph, but one that is useful in our working and thinking. Translated into English it suggests the three great orders of facts—the domain of things, the realm of organisms, the kingdom of man. Much lies in the choice of a word; it is not capriciously that one speaks of the *domain* of things, the *realm* of organisms, the *kingdom* of man. The diagram or graph can be elaborated in all sorts of ways; thus the sociosphere invades the biosphere for good and ill; when man domesticates animals and

cultivates plants, he is taking part of the biosphere into his own kingdom. Plants produce oxygen, that is the biosphere ameliorating the cosmosphere; the beaver makes a canal or dam, that is the biosphere altering the cosmosphere. Or again the biosphere may operate on the sociosphere, as when some terrible parasite like hookworm forms a heavy cloud over a large fraction of the human race. Or the cosmosphere may invade the biosphere, as when a great change in temperature alters the whole fauna of a continent.

Now corresponding to this graph there is the old-fashioned system of the sciences as suggested by Herbert Spencer. He recognised five great sciences—sociology, psychology, biology, physics, and chemistry. Nowadays, as we all know, physics and chemistry run into one another, and according to many biology and psychology also run into one another. Herbert Spencer's scheme was very clear and sound, and it was useful in ranking biology—the science of the nature and the continuance of life—as intermediate between the other great sciences. Biology is based on chemistry and physics, though independent of both; it forms a foundation for psychology and sociology though they are much more than it. This is the classification of the sciences which Herbert Spencer suggested, and it is a very useful one, indicating the central position of biology in the hierarchy.

Sociology.
Psychology.
Biology
Physics.
Chemistry.

In simplified form, corresponding to our graph, it may read—

Sociology.
Bio-Psychology.
Chemo-Physics.

But this is all introductory to the answer to our question:—What help can the biologist give to the sociologist? What is the bio-sociological contribution? First of all the biologist has to insist on

the threefold aspect of life: the organism—function—environment relation. This triangle (fig. 198)—organism, function, environment—is ever in the biologist's thoughts; it is the prism with which he works, with which he seeks to analyse the light of life, and he must insist on the sociologist doing the same. For no ideal, no step of progress, no ambition, no difficulty is there that has not these three sides—the organism side, the environment side, the function side. These are the three co-ordinates, to change the metaphor, with reference to which every problem must be orientated, and every ambition defined. Those thinkers and doers who do not recognise the trilogy of organism, function and environment are wrong from the start.

But of course the biologist would insist that the sociologist must change "organism" into "folk", "environment" into "place" and "function" (or better "functioning") into "work", as Le Play long ago suggested, and as we have already insisted in this book. Every secure advance in social hygiene or on any other line must take account of the three sides of the prism: organism, function, environment; folk, work, place.

The second suggestion that the biologist would like to make to the sociologist is the need for continually keeping in mind the unity of the organism. The biologist with all his faults is on the whole continuously appreciative of the unity of the organism; but while no sociologist ignores biology or psychology, he often uses arguments and phrases which imply that he is forgetting both. He often talks of man as if he were just a walking gastronomic mechanism, whereas the biologist is coming more and more to feel that the study of the organism is very incomplete unless he recognises a bio-psychology, just as much as a bio-chemistry and a bio-physics.

In spite of the ingenious Robot-biology of the behaviourists, we hold to the reality of mind—even in everyday animal life. Nothing is more familiar than the encounter between a cat and a blustering dog. The cat has a sudden storm of emotion. What the emotion is we do not know; it certainly is not fear, it is more akin to indignation. From the brain there travels by the sympathetic nervous system a message to the suprarenal bodies, and they increase their secretion of adrenalin. This potent hormone passes into the blood and is carried throughout the body. It raises the blood pressure immediately and increases the coagulability, a change that will be useful if there is going to be a wound. It does all sorts of things, including the contraction of the little unstriped muscles that lie at the base of the hairs. Thus the hairs stand on end; the cat looks twice the size it was before; and the dog finds it convenient to remember an engagement in the next street. All this takes place in less than a minute, and we know the details of it very well; but we cannot, to

our thinking, make sense of it unless we start with the storm of emotion, the "feeling" storm which the cat experiences.

In a case like this the biologist acknowledges the unity of the organism, and he pleads with his colleague working on higher spheres not to forget this. For even man may be falsely simplified into a Robot. The Industrial Age is still making Robots wholesale.

It does not seem that we have made much progress recently in regard to the relation between mind and body; it eludes us. No very essential advance has been made on the subject of the mind-body relation since the time of Aristotle. There are experts, like Prof. William McDougall, who appear to regard the mind as a sort of musician that plays upon the instrument of the body—a dualistic view which has a great deal of attractiveness. But then there are other experts, like Prof. Lloyd Morgan, who speak of the mental aspect as if it were just the inner subjective side of life—as if mind and body were the concave and convex sides of a dome, inseparable from one another. Between these views it does not as yet seem possible to choose—one is dualist or monist according to one's temperament; but the important thing is to appreciate both aspects, for both are realities. At one time the organism is predominantly Body-mind, the physiological aspect (Bio-psychosis) being accentuated. At another time the organism is predominantly Mind-body, the psychological aspect (Psycho-biosis) being accentuated. If a man is digesting his meal, this is mostly an affair of Body, for the main thing is the bodily process of digestion, a breaking up of proteins, and so forth. It is mostly Body, yet not wholly, for if the digestion is not getting on very well, and a messenger comes with good news, there is at once an improvement in the fermentative process and a eupeptic influence is evident. So it is not all body, it is Body-mind. At another time the man is in his armchair reflecting on the universe, and it is mostly of course a mental adventure. But it is not altogether activity of Mind, since the flow of the philosopher's thought is influenced by his digestion. Even when he is philosophising in his armchair he is not mind only, but Mind-body.

To recognise this commonplace is what the biologist pleads for. In every case we must recognise the shifting about from Body-mind to Mind-body and back again to Body-mind. So with your troublesome adolescent, with your sailor who comes to port, with the members of a household rubbing one another the wrong way, with anybody and everybody—they must always be treated as Mind-bodies and Body-minds. If one uses a diagram of the prism of life, one should make the sides convex like those of a spherical triangle, the outer convexness to express the objective aspect, and the inner concaveness to express the subjective. (Fig. 198.)

Does not the organism side correspond, in subjective aspect, to feeling; the environment side to knowledge; and the functioning

side to endeavour? For most feelings arise in connection with *folk*, most knowledge arises in connection with *place* or environment, and it is in connection with *work* that endeavour develops. The conative side of life is largely work-experience focussed into purpose. Thus we have feeling, knowledge, endeavour, corresponding to the old-fashioned heart, head and hand—the three sides of our being. It is this unity of the organism, at once biological and psychological, that the biologist ventures to plead for, to correct a partiality so often evidenced in the phraseology, at any rate, of the sociologist.

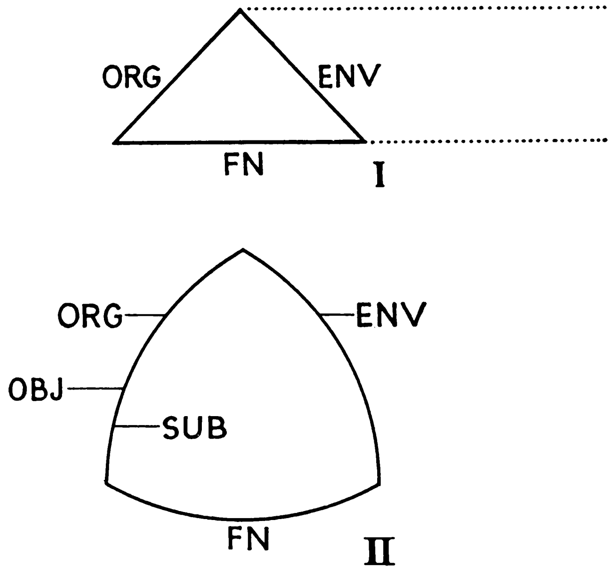


FIG. 198.

The Biological Prism.—I, The Organism (ORG) in relation to its Environment (ENV) in its functions and functionings (FN). The prism is drawn uncompleted, to suggest that all the three sides are changing. II, The convex outer surface indicates the objective aspect (OBJ). The concave inner surface indicates the subjective or psychical aspect (SUB). In the case of the environment, this is evident enough when part of the environment is animate.

Thirdly, the biologist has, of course, a great deal to say to the sociologist about heredity. If we can for the moment forget all the details about heredity, and think only of the biggest things, the first thing the biologist would urge is that the whole trend of modern research points to the conclusion that we cannot add to the number of our hereditary talents after development has got under way. It is disappointing, but that seems to be the truth. If we have no primordium, or what the Germans call Anlage, for this or that quality, we cannot acquire it. If we have no ear for music, then we need not spend money on music lessons: the initiative is not there, and no amount of prayers or tears will bring it into being. We may trade with our five talents, of course, and make them ten, but we do

not gain a *new* talent when we make our five talents ten, which is an easier thing to do perhaps than making our three six. While each of us may have our distinctive pattern, fashioned with strands which come from our forefathers, yet there is evidence that we can add new kinds of strands.

Moreover, the student of heredity would also say to the sociologist: 'These hereditary qualities are like buds, and what the buds become depends upon the sunshine and the rain and the wind and the soil. They may unfold generously or in a niggardly way; they may fall asleep altogether—which is sometimes very much to be desired—but let us remember Walt Whitman's "Buds to be unfolded on the old terms." Heredity buds to be unfolded on the old terms, which include for the child actual sunshine and rain and wind and trees and all wild nature generally; and it is difficult to evade the foreboding that the artificiality of our environment may rob the buds of those liberating stimuli which are, or used to be, necessary for their normal unfolding. Give every reasonable opportunity for the expansion of the parts of the bud, but do not expect a magical shoot.

The student of heredity has another very interesting contribution to make to sociology, namely, that man's inheritance consists in part of unit characters or Mendelian characters; that is to say, characteristics which neither blend or break up. It is very important, sociologically, to bear in mind that these strains in our being have an extraordinary power of lasting from generation to generation. We already instanced Jean Nougaret, born in 1647, who was affected by night-blindness, due to a lack of visual purple in the retina at the back of the eye, so that he could not see well or at all in dim light. Since 1647, when Charles I was King, a certain percentage of the descendants of Jean Nougaret in each generation have been night-blind. So with the Hapsburg lip, and so with delightful things like the Celtic temperament and with troublesome things like a roving disposition—they are persistent strains in the inheritance of mankind. It may be that traits once expressed in the robber baron are rehabilitated to-day in the money-grabbing profiteer. It may be that traits of Palæolithic man are still lingering in our midst, traits not only of body, but of mind. It is easy to speak about having a mind of our own, but that is the most difficult thing in the world. Our minds are much less our own than we think, for they contain, in spite of ourselves, catholic strains and puritan strains and scholastic strains, and they land us in thoughts and acts for which we spend a good deal of our time in finding what we call "good reasons." Our minds are probably full of ancestral Mendelian strands.

There is great sociological as well as biological importance in the occurrence of crisply defined Mendelian characteristics. Let us get the

point clear, taking the case of crossing an ordinary normal mouse with the peculiar variety, already mentioned, called the Japanese or waltzing mouse, which goes round and round without any particular reason. This waltzing mouse has some queer kink in its nervous system. What the peculiarity is we do not clearly know; probably some penetrating defect in the inheritance of the mouse as regards its nervous system—a defect that finds diverse expressions. For instance, the waltzing mouse is deaf for the whole of its life except for a day or two. It is full of peculiarities, which seem to hang together. Now if the waltzing mouse be paired with the normal mouse, the offspring will be all apparently normal—the peculiarity does not find expression; it is latent, not patent! All the offspring of the first generation are apparently normal mice, but when these are paired with one another, or with others of similar history, 25 per cent. of their progeny are pure normal, 25 per cent. are pure waltzers, and 50 per cent. are, like their immediate parents, apparently normal, but with waltzingness in their germinal constitution. Now let us think of the waltzingness as comparable to the characteristic of a defective human being. As long as one of these apparently normal individuals, with waltzingness or deficiency in the constitution, pairs with a thoroughly normal individual, everything in the progeny will look well; the normality will be dominant over the recessive waltzingness, and all the offspring will be apparently normal. But suppose these apparently normal defectives, whose deficiency is masked, pair amongst themselves, then in the next generation one-quarter of the children will be patent defectives. As long as the masked human defectives marry normals the children will be apparently normal, for normality is dominant over deficiency in the great majority of cases; but if the masked defectives marry among themselves, then on an average one in four children will be patently defective. This Mendelian interpretation of the masking and the subsequent disclosure of deficiency is of great social importance.

Let us think for a little of another problem—the transmissibility of acquired characters. According to Weismann's definition, an acquired character is a peculiarity of the body directly resulting from some peculiarity of nurture—whether it be environmental, nutritional or functional. There is no doubt that modifications may be induced in the individual as the direct results of some peculiarity in the individual nurture. The question is whether these modifications —for good or ill—can be handed on to the next generation in any degree; and it is an extraordinarily important question not yet definitely answered.

One remembers Spencer's remarkable declaration—very rash for such a big-brained man. He said: "Either there has been inheritance of acquired characteristics or there has been no evolution." But many

biologists at present would emphatically refuse the alternative. Without foreclosing the question, one must say that the evidence of the transmission of bodily modifications even in a slight representative degree is very far from being convincing, though there are some experimental data pointing in the direction of that conclusion. But if modifications of a beneficial sort are not hereditarily entailed, it is plainly our duty to try to re-impress them on each successive generation. That is the practical corollary. If modifications which are to the good are not hereditarily handed on as such or in any representative degree, then surely we should seek to induce similar modifications on each successive generation; and if that is done it may be that these re-impressed modifications will act as a screen, a life-saving protective screen, until a germinal variation in the same direction has time to emerge and grip.

The commonsense person, for whom we have a great respect, often says: "But do you really mean to say that the individual experience is of no account in evolution?" And our biological answer would be: "Of no account apparently as regards the handing on of any specific individually-acquired gain or loss, but of very great account in this way, that the individual experience is the time during which inborn germinal variations can be tested and put to the proof, held to or rejected." Individual experience is the time for the sifting and trying and testing of individual variations, some of which are certainly heritable.

We should not allow ourselves to become tired of the "nature and nurture" controversy, but its utility is to a large extent blurred by a confusion of thought. Nature and nurture are the two components determining the development of any character. To pit one against the other is like asking whether the waves dashing in on a particular part of the coast are due to the tide or to the wind; they are, of course, due to both; and so it is with all our features and characters, of mind and of body. All are resultants of two components, both of which are necessary. Therefore it becomes a rather theoretical question as to the relative importance of the two components—not whether one or other should be regarded as essential. We must admit that there are some callous natures, very self-contained people, very unsusceptible, who are not readily amenable to nurture, as was suggested when in Shakespeare's *Tempest* Prospero said of Caliban: "A devil, a born devil on whose nature nurture will never stick." But that is not the way with the majority: nurture does stick, and it begins nine months before birth, and it includes not only the wind, the rain and the sun and all that sort of thing, it includes the influences of the social heritage which is continued from generation to generation outside the organism altogether.

Fourthly, the biologist has much to say to the sociologist about

variations. When we study heredity, a fatalistic mood grows upon us in spite of ourselves. The consequences are so far-reaching, lasting in so many cases to the third and fourth generation, and far beyond that; we feel that all we can do is to "dree our weird". But the fatalistic impression must be corrected by even deeper study. In the first place, it is commonsense to recognise that the springs of conduct that we inherit give us sweet water as well as bitter. We have a vast inheritance of wholesome buds as well as an inheritance of some that were better left sleeping. And then again, characteristics that are progressive tend on the whole to be persistent, more lasting than characteristics that are disintegrative and deteriorative. Disharmonies do not last so well as harmonies, which is a hopeful fact. Then there is the idea, which was emphasised by Sir Frederick Mott, that certain deteriorative characteristics exhibit what he called the law of anticipation, appearing earlier and earlier in life as generation succeeds generation. They may find an outcrop in very early stages of development, and in some cases they become lethal —that is to say, they put an end to the organism, which may be from the racial point of view a good riddance. Furthermore, our social heritage, which marks us off from the beasts, is capable of improvement without limit so far as we know, and may help to counteract deficiencies in our natural inheritance.

But what is the biggest fact on the plus side? It is the continual emergence of variations. Throughout the animal world, except in a few conservative, well-adjusted types, variations are always cropping up, as everyone knows who has studied species even for a short time. Many species are in a state of flux, always turning up something new, and these variations, so very marked in mankind, are the raw materials of a possible evolution. Our duty is to give human variations a welcome if they look at all promising. We cannot produce these novel buds, but we can welcome them; we can prevent them from being frost-bitten, which they so often are. The other side of heredity, so to speak, is the continual emergence of the new. We have no recipe for genius, but it would be something if we were more determined to cease from starving genius when it appears. It is tragic that an original mind, sending new tendrils into the future, often fails because these find no support.

Of course social variations are different from biological variations. Social variations correspond to what is seen in an anthill, in a termitary, in a beehive. For instance, when a colony of ants takes to slave keeping that is a social variation, and similar social variations are frequent in mankind. But some other social variations, which lead to new movements and new departures, depend upon a biological variation, for instance, on the emergence of an individual man or woman of a particular pattern who is full of new ideas and has

some success in focussing the consciousness of a large body of his contemporaries. While the true analogies of human social variations are to be looked for in, for instance, the undertaking of a war by a community of ants, or the keeping of pets, or the keeping of slaves, other social variations may depend to some extent upon the individual biological variations of man and woman, as history and biography sometimes surely show.

Fifthly, the biologist has a great deal to say about selection. He has to emphasise to the sociologist that, so far as biology knows, all good things are established and furthered by sifting, Nature's sifting being a good translation of natural selection. All through the animal kingdom for millions of years a sifting process has continued, and the sieves have evolved as well as the material that is sifted. In early days among mankind there was much of this natural sifting—by wild beasts, by flood and storm, by poisonous herbs. By many a natural sieve was early man sifted. And still there continues in modern mankind some traces of natural selection, in the case, for instance, of certain discriminating diseases which kill off the weak rather than the strong. But, as everyone knows, natural selection in mankind has practically passed into abeyance, and that for two reasons. One is the growth of social sentiment which prevents us from being cruel in the present, though it does not prevent us from being cruel to the future. By the growth of social sentiment—humane feelings, as we say—we are prevented from allowing natural selection to operate to any great extent. And the second reason, which is so well emphasised in Trotter's *Instincts of the Herd*, is that the very fact of there being a society extends a shield over types which would perish unless the society sheltered them. For instance, in a society of slave-keeping ants there may be members of the "master" species who are not only unable to forage, but who cannot even use the food when it is brought to them. They have to be spoon-fed by the slave-workers. It is obvious that in a couple of days without a society, these degenerate masters would all perish; under the ægis of the society these impossible individuals, who require to be fed by the workers of another species, continue to flourish. But human society is always doing this sort of thing—it is protecting individuals who without the protection of society could not live for more than a short time. And this brings us to what Herbert Spencer called the dilemma of civilisation. He stated it in two or three sentences that ought to be displayed in letters of gold in some prominent place in every city: "Any arrangements which in a considerable degree prevent superiority from profiting by the rewards of superiority, or shield inferiority from the evils it entails; any arrangements which tend to make it as well to be inferior as to be superior, are arrangements diametrically opposed to the progress

of organisation and the reaching of a higher life." These are most forcible and wise sentences.

The biologist has to emphasise the struggle for existence. His study of animate nature shows him that things of value are gained and are kept by struggle and endeavour. But we must get back to Darwin's conception of the struggle for existence, which was so wide and so wise. He insisted that the struggle for existence is a formula to include all the endeavours which are made against environing limitations and difficulties, all the answers-back in the endless clash of life with things. At the one pole there is sharpening of teeth and claws; at the other pole there is the gathering of 2,379 feathers to make the quilted nest of the long-tailed tit. Darwin pointed out that both these are included in the biological concept of the struggle for existence, which includes all the endeavours that creatures make against environing difficulties and limitations. At the one pole, from the Amœba to man, there is cannibalism; and at the other pole there is self-subordinating parental care and many a form of mutual aid. One pair of blue tits on a long summer day of sixteen hours brought to their nestlings two thousand caterpillars, which, from the nestlings' point of view, was a fine exhibition of parental care.

To put it in a sentence—man's endeavour must be not only to prevent relapse to the cruder forms of the struggle for existence, of which the crudest is cannibalism; but to rise to the higher forms of the struggle for existence in which effort becomes an endeavour after well-being. *What is the biological counsel?* There must be segregation. One is very tired of the Jukes family, but when five bad women in less than a century and a half can have six hundred mentally defective descendants there is something very badly wrong. There must be some segregation. And then one must welcome, although it is sometimes very hard, sound social selection, when what we would call efficiency tests are enforced, and a man who is thriftless and lazy and irresponsible is shifted. He cannot be eliminated, but he can be shifted. There is also need for a more carefully eugenic criticism of expenditure, which is a very powerful lever; and there is the education of public opinion against ob-selection, as in advertising for a gardener "without encumbrances", or in dismissing a female teacher when she marries, or in founding fellowships which involve celibacy. And again, there is the education of public opinion against those marriages which sow tares amid good wheat.

Sixthly, the biologist feels keenly the danger of false simplicity. He himself suffers so much from the false simplicity of the materialists, who insist that chemistry and physics account for all the phenomena of life, that he is very sensitive to false simplicity in other fields. No doubt there is a legitimate and indispensable and

illuminating chemistry and physics of the body, but when we have got both of them at their best we have not got an account of the whole life of the creature. The biologist would declare against the false simplicity which calls mankind a herd—that is a biologism—or which speaks of mankind as a human hive—that is a biologism—for human society differs from herd and hive in several deep ways. Man has reason (conceptual inference) whereas animals have at most intelligence (perceptual inference); man has got language whereas animals at the most have words. Man has a social heritage of which the beasts have only an adumbration; man has permanent products to an extent that is only hinted at in the beaver village. He shares in his own evolution in a conscious direct way that is not known among animals.

It is the duty of every biologist to expose the seamy side of the beehive to which we are so often referred. The beehive is a most marvellous organisation; the more we know about it the more marvellous a community it appears. There is a remarkably fine display of wealth in the hive—the stored energies of the honey in the honeycomb. There is a high degree of vigour in the beehive, for, apart from the Isle of Wight disease, and foul brood and a few other disturbances, probably due to man, the beehive is a very healthy community. So far the bright side of the beehive, but lift the curtain a little and look at the seamy side. The queen, exaggeratedly specialised for reproduction, is the only normal mother. The workers form a huge proletariat of arrested females under the sway of instincts sometimes almost maniacal. Most of the drones—the male reproductive caste—are quite futile. Sometimes only one effects anything—the more or less fortuitously successful male who overtakes the queen on her nuptial flight. Think of the terribly short life of the worker-bee, say six weeks in the summer time and seldom over two months, with a brain that goes steadily out of gear with over-fatigue, as Hodge has proved. Moreover, to the human male the massacre of the drones in the autumn is an appalling fact. The seamy side of the beehive deserves to be exposed; yet biology has to offer to the sociologist many a hint from which his social science may profit, many a hint which the social reformer, if he is alert, will utilise.

THE BIOLOGICAL PRISM.—Every practical problem we have to face in modern life has three distinct aspects, and this is particulatly important in regard to social hygiene. The living creature—the organism—is one aspect; the surroundings—the environment—is the second aspect; and the activities of the organism in that environment constitute the third aspect. We are so apt to be partial in our enthusiasms and ambitions and difficulties—thinking only of one side, and sometimes only of a fraction of one side, instead of thinking,

or trying to think, of the three aspects, the organism, the environment and the functioning. No line of biological progress can be sound and secure that does not take heed of these three commonplace, common-sense aspects of the problem. We are apt to concentrate our energies on one thing; and that is to a certain extent to the good, because we are usually most efficient in connection with the things for which we care most. Yet even our practical efforts are blunted if we do not correct our mental astigmatism. We suffer, all of us, from a lack of stereoscopic vision in our mentality. One authority says everything depends on food: it is question of nutrition. Another expert says it is housing that is all-important, and, of course, he is right up to a certain point. We want houses that are not simply built to be hidden, but houses that may be homes—yet what is the good of a well-constructed house if the owners keep rabbits in the coal-cellar and the coal in the bath?

Sir William Ramsay once said that human progress consisted in increased economy in the use of energy. Now that is admirable up to a certain point, but in such an economical definition of progress, think what has been omitted, in regard to life, mind, and society. Prof. Karl Pearson says that the main thing is to breed from the best and to prevent the unfit from having children. A fine ideal, of course, and part of the eugenic ideal, yet limited by taking no account of environment or of function. What of a hypothetical fine breed if they continue to live in a black country or in a slum?

We like reforms carried out for other people and to be left alone ourselves. But it is not that sort of thing we are declaiming against so much as partiality of view, and our discussion here is an attempt to see things more wholly. In other words, we wish to visualise the biological idea of the prism of life. Biologists seldom fall into the common fallacy of one-sided vision, for they are always thinking and working with the three aspects, organism, environment, functioning, plainly in view—meaning by functioning not only breathing and digesting and the other everyday processes which are almost wrapped up in the word "organism", but rather the activities and ongoings of the organism, e.g. in its search after mates and food. We must think of the organism as a functioning body spending a great deal of its energy in regulating itself and keeping itself going; but what we mean by functioning is rather the action and interaction of the organism as a whole on its environment. This, then, is the prism by which the biologist seeks to analyse the light of life: Organism, environment, functioning; in plain English (1) the living creature; (2) the surroundings, including everything that has an influence; and (3) the activities of the creature in reacting on its surroundings. Though often ignored, this corresponds to the sociological diagram. For, as has been explained, all social processes must be envisaged within the three categories of (1) the people or

folk—that is the organism; (2) the place—that is the environment; and (3) the work—which is a better word than function, because it suggests external action on the environment. Therefore we would suggest for expository purposes the following diagram:—

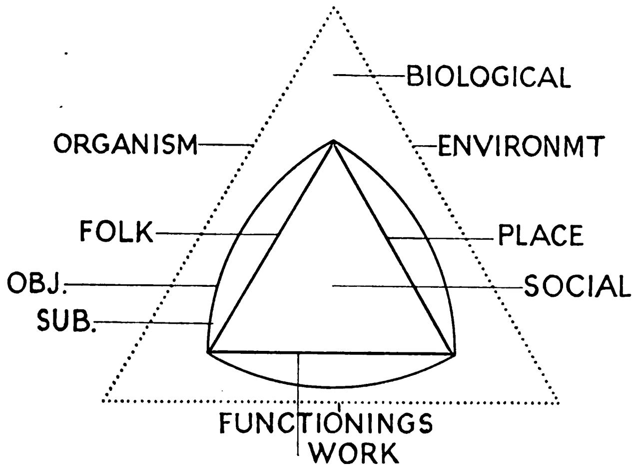


FIG. 199.

Biological and Social. The outer triangle is biological, with its organismal, functional, and environmental aspects. In the social sphere, Folk, Work and Place correspond to Organisms, Functionings, and Environment; in the Biosphere. The convex surface (OBJ.) indicates objective aspects, the inner surface (SUB.) indicates the subjective life.

This is a spherical triangle, of which the outer convex side may represent the objective and physiological; the inner concave side the subjective and psychological. If we visualise it in this way we get away from illegitimate materialism—in other words, away from the plane triangle.

Now out of this graph there arises the formula already suggested as a descriptive definition of life. We may very simply, and to a certain extent, adequately, represent life by the fraction—

$$\frac{\text{Organism—Function—environment}}{\text{Environment—Function—organism}} = \frac{\text{OFe.}}{\text{EFo}}$$

This is a sort of intellectual shorthand, expressing the fact that life implies a continual balancing of the numerator and the denominator. The numerator suggests the Organism acting upon and trafficking with its environment; the denominator suggests the Environment acting upon and influencing the organism. At times the Organism is the more active factor, dominating the environment. At other times the Environment paralyses, stimulates, depresses, inspires, the organism "o" in its grip. Among some people, especially in north temperate countries, the numerator is often the more important. Thus the hunter is always more concerned with the numerator; he emphasises the idea of the organism, unwilling to accept defeat, acting on the

environment and conquering it. On the other hand, how apt is a member of an Eastern race living in the desert to think more of the denominator, the environment having everything in its grip, against which it is hopeless to struggle—the environment which one must endure, to which one must submit. To peoples in the Arctic regions and in the desert fatalism is naturally the prevailing philosophy of life. The formula $\frac{\text{OFe}}{\text{EFo}}$ is in itself no definition of life because the word "organism" comes in, and a definition must not include the

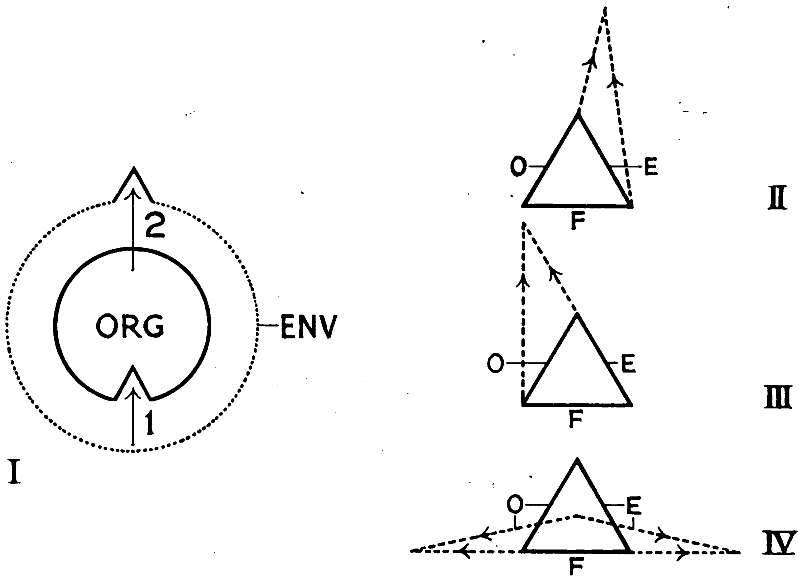


FIG. 200.

Organism and Environment. I, The Environment (ENV) may act on the Organism, producing a dint or modification (1). The organism may produce a change in its environment (2). II, The organism has an uplift, and pulls up its environment. III, The environment improves, and raises the organism. IV, The functionings are depressed; organisms and environment follow.

thing defined, but it is a useful and suggestive shorthand description of living. Organism acts on environment and environment on organism. Take, for example, a colony of beavers: they cut down the trees of a forest, they build a dam, they make a canal—that is acting on the environment. The beaver village illustrates OFe, and so does the earthworm, tunnelling in the ground, displacing the earth, and indeed eating it. But when a frog lies in winter in a hole in a bank or in a drainpipe, mouth shut, eyes shut, nose shut, everything shut, heart beating feebly, breathing movements imperceptible, that illustrates EFo, the environment holding the organism in its grasp. In plant life there is always more emphasis on the denominator, because the plant is so characteristically recipient of the sun's energy, and does not move about.

It will repay us to use the simple graph of Fig. 200, especially if it can be considered not on the flat, but in the three dimensions. For instance, suppose the organism should degenerate, then how apt it is to draw both the function and the environment down with it, a very familiar change in the human tragedy. But suppose the organism has an uplift, then how strong it often is to draw its environment and function up with it. If one interprets the basal line as functioning in the wide sense, it may serve to represent the exertions man takes to keep fit, to find shelter, to get on and so forth. When the struggle is too keen and the base too long drawn out, as often happens, how apt is this to depress both the organism and the environment. In some places, known to us all, where the struggle for existence is terribly keen, the organismal life has lost much of its pitch and the environment has sunk to a dreary monotony. Part of the human ideal is to shorten the necessary activities for mere sustenance, and to lengthen the other two sides of the triangle, the organism's own life and the environment. Perhaps mankind is moving towards a compression of the efforts that are necessary for gaining subsistence and the like; and this will be to the good if it is associated with a raising of the pitch of the organismal life and the beautifying of the environment. Secure progress depends not a little on an understanding of the biological prism.

There is a little worm, Planaria, about the length of half one's little finger-nail, a simple and interesting creature, which has been more experimented with than any other animal except the tadpole. If a young Planaria is reared on the minced flesh of the freshwater mussel—a food which it dislikes—it grows in a sulky sort of way. It soon stops growing, and becomes an old youngster that does not grow up—and all because it was forced to eat a kind of food that did not suit it. How quaintly suggestive this is as to the value of a varied diet, as to the risk of too much porridge, at the one extreme, and *toujours perdrix* at the other!

It is a mistake to think that this relation of the organism to the environment is at all an easy subject. Suppose we draw a circle, place the organism in the middle, and try to see in what different ways the organism may influence the environment, and how in its turn the environment may play upon the organism. See the organism throughout its life running the gauntlet of never-ending environmental influences—mechanical, chemical, physical, animate. These influences take many forms. (1) Thus, to begin with, the organism is entirely dependent on its surroundings. The effect of taking the organism wholly out of its essential environment is familiar in the fish out of the river. Take away the oxygen, for instance, and life is over. (2) Secondly, the organism is stimulated by its environment. When we go out into the sunshine our pulse changes its rhythm, and it is easy to prove that we enjoy the sunshine quite

apart from its warming influence. (3) We live in the sunshine for a day or two, and we become temporarily more or less sunburnt. This does not last, it has disappeared in a week or two; it is a temporary *adjustment* of the organism to the environment. (4) We work in the tropics for twenty years and are tanned. There is a positive modification in our skin that lasts throughout life. When we come home to enjoy our leisure the tanning persists—it is a permanent *modification.* (5) The influences of the environment may first affect the body and then reach the germ-cells lying within the body. That is especially

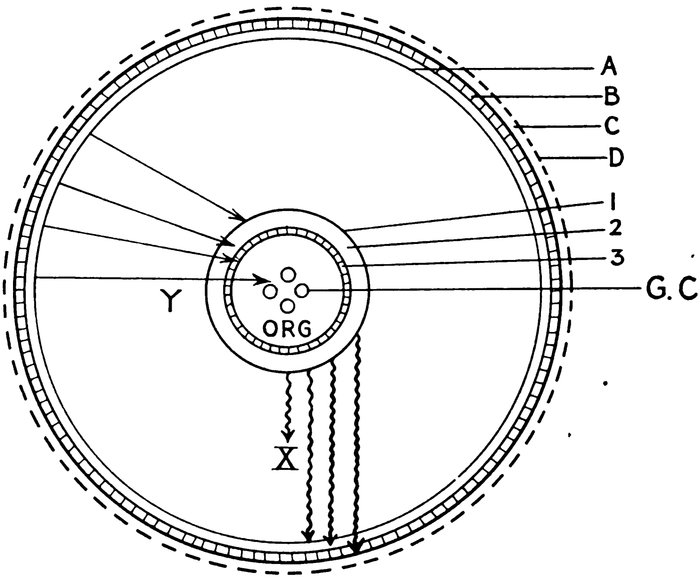


FIG. 201

Action and Reaction between Organism and Environment. The outer circles (the Environment) include (A) animate, (B) Physical, (C) Chemical, and (D) Mechanical influences. As the arrows (Y) show, these may penetrate to different depths of the organism, to the ectodern (1), to the mesoderm (2), to the endoderm (3), and even to the germ-cells (G.C.). From the organism there may be influences (X arrows) reaching various zones of the environment.

true of climatic influences; the body is primarily influenced, but so are the germ-cells, and thus a subsequent generation. (6) The environment may act as a variational stimulus. Prof. Tower shut up potato beetles in a finely made cage of steel and plate glass, in which by turning a handle he could alter the humidity and temperature. He subjected the beetles to unusual conditions of temperature and humidity when the reproductive organs were at a certain stage in their development. The beetles themselves are not amenable to environmental influences, except of a very drastic kind, but at a critical time the germ-cells seemed to be affected by the change of environment, and the offspring showed many novelties, some breeding true. (7) The creature may be modified by peculiarities in

its environment, and these may affect the germ-cells and the progeny. But there is thrust as well as parry. The organisms are not only modified by the environment; they often select their environment. (8) Finally there is the sifting action of the environment. The environment has been all through the ages a sifting agent, and there has been an evolution of sieves as well as an evolution of the material sifted. Thus we see how impossible it is to take a facile view of the relations of the environment and the organism; we have mentioned eight kinds of influence and have not come to an end.

It would take a long time to discuss the human environment, but let us think for a little about some of the factors. Thus as to air, much importance attaches to the efforts that one needs to make in the beating of the heart and in the breathing movements to cope with the slight quantitative differences that occur in the composition of the air. When the oxygen is slightly less than usual the work of the heart and lungs is greatly increased, and it is this additional work that tires us, both adult and child.

Then there is the importance of movement in the air. The work of Prof. Leonard Hill has shown clearly that it is the circulation of the air that is so vital. Not only does it prevent accumulation of microbes, but it promotes evaporation from the skin; and for some reason not at present very clear, the actual movement of the air helps the respiratory exchange of gases. Thus one remembers how Prof. Hill shut up certain students in two rooms, where the only difference between them was that in one there was an apparatus to keep the air moving. Those in the room with moving air were least tired.

Many volumes have already been written on light: the light that kills microbes; the ultra-violet rays which, though they unfortunately do not come through ordinary glass, act as a stimulant to growth and development; the light which has a subtle psychological influence. How far-reaching is the light!

As to warmth, it is not the difference of temperature that is so important, because life is only possible within very narrow limits; what is important is that when we get over-heated, for instance, there are secondary consequences, which affect us deeply. If there is over-heating and the sweat glands are not operating any too well, difficulties arise, for harder work is demanded from the heart, and so forth. This happens not only when the sweat glands are not operating well, but if the clothes worn are too thick and heavy, if free evaporation from the skin is prevented, and if the heat in the body is not in circulation so to speak. There are many very serious difficulties involved in over-heating. One can hardly forget Prof. Leonard Hill's graphic disrobing of a curate — though over-clothing is not confined to the clergy. The first thing he took off was a wool-lined motor-coat; then a cardigan jersey; then a wool-

lined waistcoat; then a Jaeger woollen shirt; and then a woollen vest. So this man was actually wearing five skins beside his own.

In regard to food, of course, there is abundance of wise counsel. The important thing is to realise that food is necessary for growing, for repairing wear and tear, for keeping up the animal heat, and for muscular work; and it stands to reason that if we are not growing and working, we should not be eating so much. If there is only a little work to be done, there should be less food. Common sense this is, and yet we are apt to forget that the amount and character of the food should be decided in relation to growth, work, wear and tear, and climate.

There is still much to say about work and function, but, thanks to the heroic efforts of the medical profession, occupational diseases are rapidly dwindling away. In our student days there was a well-known big volume called *Diseases of Occupations*, but we have been told by those who know that most of that volume is now ancient history, for there are few of the really detrimental occupations now being tolerated. And here, of course, we should remember that the putting an end to diseases of occupations is largely in our own hands, for the criticism of expenditure gives us a powerful lever. It rests with us by our expenditure to decide whether certain occupations should continue or not. If you are giving a present, do not let it be a piece of modern carved ivory, first because it is likely to be bad, and secondly because carving ivory is one of the deteriorating occupations, since no means has yet been devised for preventing the very fine dust getting into the lungs. We read in the papers recently a note as to the revival of the cut-glass industry, and we could not help feeling sorry, for it was far from being a wholesome industry in days gone by, and the difficulties have not been overcome. If you are giving a present, therefore, do not give a piece of carved ivory or cut-glass, give rather a sketch, or something of a like artistic nature, so as to help the artist, who is always having such a hard struggle for life. In any case, it rests with us by our expenditure to regulate whether unwholesome occupations develop or disappear.

Let us recall a well-known fact in natural history which is very suggestive. In the hills of the white ants, as in the hills of true ants, there are frequently guests, and these guests are usually little beetles or two-winged flies. They are tolerated just like cats in a human dwelling. Now in certain cases these guests suffer from a most extraordinary condition known as physogastry. It is one of the few cases of something approaching disease in wild nature. It is an interesting and curious condition. The beetles. which are well-proportioned creatures to start with, begin to exhibit a terribly swollen abdomen; then they get very sluggish, their wings drop off,

and finally they become more or less blind. To what is this extraordinary condition due? According to our best authority, Prof. W. M. Wheeler, the physogastry is due to the fact that the beetles are living in darkness, stagnancy, humidity, and airlessness, and that the hosts insist on feeding them over-abundantly with carbohydrates. A parable indeed.

There remains the organism, which is a product of hereditary nature played upon by nurture. What can we say? Of much interest is Karl Pearson's pamphlet, not very clearly titled *The Right of the Unborn Child*. It does not really deal with that subject at all, it deals with the duty of not allowing certain kinds of children to be born. The point is this, that Karl Pearson took one thousand boys from one school in London and investigated their eyes, or got some expert to do so. He tells us in great detail, we are sure with perfect accuracy, what was wrong with the eyes of many of these boys—a lack of sphericity in the cornea of the eye and a lack in the adjustments which secure that the image formed by the lens is thrown immediately on the retina, and not in front of it. When the image is not projected precisely on the right place, there is a diminished acuity of vision. This implies astigmatism—an inability, for instance, to see the blackboard clearly, an inability for which the fathers or even the grandfathers of these boys were responsible. Nowadays the school physician detects the astigmatism, and the boys are given spectacles. But that is not the point. Out of the one thousand boys in that one school, 222 suffered from severe astigmatism. That seems very alarming, especially as it is only an example of the kind of thing that is happening everywhere. Prof. Pearson makes the point that the 222 boys were so badly astigmatised that none of them could have survived in prehistoric times, for they could not have seen the enemy or the booty. For huntsmen in palæolithic times it was all-important to see with precision the animal hunted; they had to slay it or else be slain; selection for clear vision was stringent. But nowadays we supply the optically defective with spectacles, and, although they cannot enter the Army or Navy, they can adopt many professions. They flourish and have children like themselves, and so the number of cases of astigmatism goes on increasing. Selection for clear vision has largely ceased. This is a parable too, because there are other defects, even more serious than astigmatism, which are increasing the burden of deficiency that we are handing on to the next generation.

But our main point is to explain the biological prism, and to show how, by getting into the habit of thinking of all the three sides of a spherical triangle, we may avoid *mental* astigmatism, which is as undesirable as the physical.

BIOLOGY AND HUMAN LIFE

THE TRAJECTORY OF LIFE: ITS SEQUENCE OF RISKS AND REWARDS. —From a bio-sociological outlook, we come back again to the idea that human life is like a trajectory, a curve of ascent and descent: a curve on which there are successive arcs—infancy, childhood, adolescence, love-making, maturity, ageing, senescence, dying—which can be lengthened out or cut down according to nurture: arcs, each with its triumphs and its joys (even in senescence!) and each with its tragedies and risks. The underlying practical idea, with which we are all familiar, is that our task is to make the most and the best of each of these arcs on our life curve, and that success depends upon our endeavour to gain positive health both of body and mind. The idea of life as a curve or trajectory is very old, though there are few books in which this simple graph finds expression. It seems strange that such a picturesque and telling image should not be used oftener: the idea of a bridge over which life has to make its way, ascending, then for a while on the level, and then descending. For it is plain that in every life there must be a period of developing, growing, strengthening, improving; and then comes the decline, the *facilis descensus*, the downgrade towards senescence. As previously explained, the plant kingdom has arcs similar to the animal kingdom—sprouting, growing, leafing, flowering, fruiting, seeding, withering—the familiar story of the trajectory of the higher plants. It is interesting to follow this out in a little detail, noting how the form of the curve differs in different types, and in relation to different conditions of life.

For instance, in the case of the mayfly, there is a long youth, two, three, or sometimes four years, then two or three evenings of active adult aërial life, reproducing without feeding, and then the sharp fall to death. There is one species of mayfly which has actually a single hour of adult life!

In contrast to that, think of an animal like an elephant, which sometimes remains beside its mother for ten years, a long period without great responsibility. Or, again, take the curious case of the common eel. The young eels or elvers which come into the British rivers from the Atlantic are already two and a half or two and three-quarter years old. In the course of their journey to our shores from a stretch of sea towards the Bermudas they have undergone a metamorphosis from knife-blade-like glass-eels to cylindrical elvers; they continue to develop in the quiet waters of the rivers; they become reproductively mature in five to eight years, and then make for the open sea—a long journey—ending in death after spawning. This is another case where the infantile and adolescent life is greatly prolonged, but the adult life stops abruptly.

We have, then, the idea that the trajectory of life consists of different arcs which are, to a certain extent, elastic, that can be lengthened out or shortened down for the individual. It is a familiar fact that some people are young till they die. When they die they are old only as regards length of years, which is a very partial measure of life.

Let us think for a little of each of the arcs of the trajectory. Human life is like a rainbow—there are two slopes—the slope up from ante-natal life to adolescence and the slope down from the waning of mature strength to death. Between them lie various arcs on the crest of the life curve.

Before Birth.—Robert Chambers, the founder of the great publishing house of W. & R. Chambers, who wrote *The Vestiges of Creation*, was a shrewd biologist. In his famous book he gives expression to what seems a sound idea, that the prolonged ante-natal period tends to develop better brains. A long ante-natal period or gestation means a long period of quiescence during which the nerve-cells develop, and it is a very important fact that we never get an extra nerve-cell after we are born. We have nine thousand two hundred million nerve-cells in the cortex of our fore-brain, but these are never added to after birth. The whole contingent is, or should be, present at birth. Therefore enormous importance attaches to the quiescent ante-natal chapter during which these nerve-cells are formed. One can understand many things from this point of view: thus an elephant has an ante-natal period of twenty months or more, and a foal of eleven months; how intelligent are these two animals! If all the nerve-cells are laid down before birth, the interlinking relations between them coming later, one sees the importance of letting the mother have a quiet time, a time when the developing offspring should not be over-stimulated, a time when some of the maternal hormones are transferred into the offspring. And so we may pass from that hidden chapter, the ante-natal slumber, with emphasis on the fact that it is the time when our whole nervous system is laid down.

Babyhood.—In the second chapter or arc we have to deal with a helpless, fragile, unprepossessing yet extraordinarily fascinating young organism. If one has the good fortune to visit a Baby Show, what are the biological impressions that rise in the mind most markedly? The first is an object-lesson in variability. These babies vary: no one baby is like another; each is itself and no other, each a new individual. The Baby Show is a revelation of the raw materials of evolution, some of them the most precious things in the world. How these new departures should be prized, for who can tell what this or that one may become?

Secondly, the biologist reflects that these babies are like so many buds--buds which are still close-packed, but which will be unfolded;

and he knows very well that the unfolding of these buds will depend largely on the nurture they receive. So he gets away from all controversy about "nature and nurture"; for he is sure of this, that the nature of these buds will express itself in proportion to the generosity and the wholesomeness of the nurture they receive. Thirdly, as he looks round that Baby Show he sees enough to puncture that widespread fallacy of equalitarianism which is so rife in uneducated circles, for he is quite sure by actual observation that these babies are anything but equal; they are born with all sorts of pluses and minuses. Equality is to the biologist the biggest of fallacies. As you walk away solemnised, the ever-jocular friend says, "Well, what do you think of the babies?" and you answer, "Well, not so bad, but they might be better." When he rejoins, "But how can they be made better?" you turn savagely on him and on yourself, and answer, "The recipe for better babies is better parents."

TENDER YEARS.—We pass to the next arc or chapter of *Tender Years*, when the entrancing bundle of variabilities is now a delightful infant. We are speaking of the period under three years old. Sir Ray Lankester long ago drew a very important contrast between the little-brain type of organism and the big-brain type. The little-brain type of organism reaches its climax in ants, bees, and wasps, and is rich in ready-made tricks. It has a repertory or capacity for doing apparently clever things, which is called instinct. The big-brain type has relatively few instincts in the strict sense. It has more in the way of generalised pre-dispositions, which do not quite correspond to the very precise instinctive rules of behaviour that the zoologist studies in ants and bees. But the positive significance of the big-brain type, such as we see in horse, dog, elephant, monkey, and man, is that though it is born with very few instincts and is poor in any ready-made repertory, it is born rich in the power of learning. Hence the importance in infancy of doing nothing that will limit the plasticity of the big brain. Since the brain is of this particular type, i.e. poor in instincts but strong in educability, the point is to keep it plastic, not to impose limits on it, especially at this early time. This is a conviction the biologist always has about children of tender years: leave the brain plastic. That is the line of human progress.

We cannot look on these children of tender years without recalling the wise saying of Lucretius: "Children by their caresses broke down the haughty temper of their parents". There is an ethical value in the prolonged infancy of mankind, for that period of helplessness engenders in the parent a gentleness and sympathy that would not otherwise be readily evolved.

It is generally agreed that there is, to a certain extent, a recapitulation of racial history in the lifetime of an individual. In dealing with children, hoping to appreciate and help them, one must keep

this recapitulation idea in mind, without exaggerating it into a fallacy. Thus the recapitulation expresses itself in the restlessness of childhood. The young child is a motor-organism to whom it is unnatural to sit quiet; it is influenced by the promptings of its ancestry, roaming about and exploring, doing anything but sit still. To repress this is dangerous.

Part of the work of education is to shorten the child's recapitulation of the racial history, else we should never get past childhood. This shortening includes the supply of suitable liberating stimuli, and one of the great problems of childhood—and of the school—is just the guidance of liberating stimuli, from books to toys. It is common sense that the last, to take a little thing seriously, should never be very sophisticated. The proud father goes to Regent Street and buys the most expensive toy: he means well, but he does ill. It is the simple, most unsophisticated toy that is wanted in the tender years; but it should be beautiful, not crude, from the very start; for the child is susceptible to beauty to an extent not yet appreciated. Hence also the importance of having from the very beginning, as far as may be, some of the fundamental impressions of the country. We live in a mechanical age, and we are apt to get away from the fundamental impressions of the countryside. Even in towns, however, they are afforded to some extent by parks and gardens.

CHILDHOOD.—In childhood there is a continuation of development, and therefore, since there are many centres in the brain which are still being developed with ever-increasing intricacy of interlinkages, it is a period when there should be much rest and careful feeding. If we are studying the development of the lung in a chick, we find that up to a certain point inside the egg this development goes on independent of the outside world, except that some oxygen passes through the shell. The development proceeds with an organic momentum which carried it on from stage to stage inside the egg during the first twenty days; but there comes a time, normally about the twenty-first day, when the lung will develop no further unless the creature actively breathes. This is a parable—a great lesson for childhood—the importance of the functional factor in development. The momentum of inheritance will enable the organism to reach a certain stage, but beyond that stage there must be functional activity—actual doing. The lung must be used if it is to advance any further. This is, of course, embodied in many theories of educational progress by action, by doing, by self-activity.

Another biological impression of childhood is its extraordinary impressionability. A child is like a photographic plate to an extent which only those who know children well have realised: they see things we have no idea of their seeing; they pick up things we never noticed. And we note that the value of the indirect impression is

incalculable. When a child sees the mistress carefully hiding away at the end of the excursion picnic every scrap of paper, although she never utters a word, the lesson sinks in and remains unforgettable. We remember, long ago, going with a master in Zoology to a seashore, a very favourite spot, and seeing him replace the flat stones which we had turned over to see the treasures beneath. He knew that other students were coming next year, and if the stones were not replaced there would be a poor gathering. Not a word was said, but on the next excursion we did not forget to replace our upturned flat stones. When a child sees the teacher gently replace in the earth, without saying anything, the sundew which the excited young botanist had uprooted, a lesson is learned that is never forgotten. The child is extraordinarily impressionable, as much indirectly as directly.

Before birth, for some strange reason, there is an activation of sex hormones in the child; but for many years after birth there should be practically none; and the point here is, of course, that well-meaning people should be instructed to refrain from certain kinds of fondlings which are apt to activate and awaken an activity which during the whole of this childhood period should be absolutely quiescent. It only needs to be suggested, surely, that there are certain kinds of affectionateness which, from their nature, are reprehensible and may lead to trouble in after-life.

Then, above all, during this period, there is the function of Play, the importance of which has been emphasised so much by biologists. The importance of play is fundamental: not only is it the safety valve for the overflowing motor energies, but it affords free elbow room for individualities, originalities, new departures which, if they do not find outlet in play, are apt to express themselves inconveniently later on. It is a time when without responsibilities some really useful originality may be expressed. Thirdly, play is the young form of work. In all playing animals the play bears definite relation to the mode of life which is practised afterwards. The kitten plays at hunting, because the kitten is a carnivore; and the lambs of the field play at King of the Castle, which appears to bear some relation to the clambering of the wild sheep. Play is the young form of work, an unconscious indispensable apprenticeship to future duties; for he will work well who plays well. Fourthly, the ethical value of play is that the child learns in play better than by any other experience what "playing the game" means—learns the valuable lesson of self-subordination—the lesson of give and take. So whether one thinks of play as a safety valve or as elbow room for individualities, or as the apprenticeship to work, or as an opportunity for learning to "play the game", it is invaluable. All work and no play makes Jack not only a dull boy but a bad boy.

ADOLESCENCE.—This chapter raises an important series of

problems. We cannot do more than recall some of the fundamental facts. Firstly, adolescence is a period when there is a re-acceleration of growth; therefore, it is a time when the growing life requires plenty of sleep, rest and food. Secondly, it is a time when definite re-arrangements are going on in the body, in the nervous system in particular; such as new emotions and ambitions, which must be regarded generously and tolerantly, provoking as they so often are. The cruelty and the insurgence of youth are familiar, but let us try to appreciate them biologically; they are the expressions of a new outlook. Thirdly, it is during this time of adolescence that the reproductive hormones find normal activity—sometimes in a very gentle way like the dawn, sometimes in a stormy way like a volcanic explosion. In some way or other the sex-urge and the emotion of love must find expression. Here arise much-discussed problems. Only a few suggestions can be made here. It is possible, it seems to us, that part of the modern emphasis laid on sex difficulties is mistaken, that there is a tendency to some extent to make a scapegoat of sex, whereas what is really wrong is a poverty of nature. In the second place, there is much hope in having sound biology on the one hand and definite physiology on the other. We must help our children to face the physiological facts, teaching them as impersonally as possible, getting the facts clear and leaving the deductions to be drawn therefrom. Of course, much more is needed than physiology; we must help the young to think of these things in a big way, to hitch the wagon of sex to the stars, we must remind them from history that some of the finest things in the world have been done because of the love between men and women. Of course we should nail to the counter the lie, which is so prevalent, that continence in young men is bad for health. That lie, at any rate, should be exposed to the senior boys. No doubt we are moving away from the idea of preventing people from going wrong by fear. But perhaps there is a wholesome fear. There is utility in telling the youth what the late Sir Frederick Mott has told us about the consequences of over-indulgence on the man's side in early years. Mott pointed out the correlation between the opposite of continence and mental disease in later life. This is a question for experts, but if it be true that sexual intemperance is apt to be correlated with a nervous breakdown in later life, then the fear of that should be rather fostered than ignored. Perhaps we should have more fear of a great many things—fear of obscurity, fear of coming to a rapid conclusion, fear of a great many evils. Perhaps we must not too hurriedly try to dispense with the fear-factor in education, although greater and more powerful is what Dr. Thomas Chalmers called "the expulsive power of a new affection."

Following the curve a little further we come to *falling in love*, or, as it should be called, *rising* in love—a great chapter in the trajec-

tory. In regard to this important matter it seems clear from the outlook of psychology, biology and common sense, that there are in ideal risings in love three distinct notes: the first is the note of physical fondness (which should be indispensable), the second is the note of esthetic attraction, and the third is the note of psychical sympathy of personality for personality. All these three notes we can recognise in the higher reaches of the animal kingdom—at their highest among the birds. The root of the matter, so to speak, is physical fondness; then there is esthetic attraction, often very subtle; this is sublimated in the psychological attraction of personality for personality. All this we find expressed in birds, and a great school lesson is to indicate that one of the big facts of organic evolution has been the rise from physical fondness to esthetic attraction, and thence to what we can only call love in the mating birds.

MATURITY.—Then comes the period of married life, and here we cannot but be absolutely simple. There are three sails on the voyage of married life, if it is to be a happy one: the first sail is organic fondness, without which the voyage is apt to end in shipwreck; the second sail is esthetic attraction, which may take many forms, even down to dress, which may be an expression of the self; and the third is a certain amount of intellectual and emotional sympathy, which will find its climax in working together for some big endeavour. Of course we do not mean that man and wife must belong to the same political party, but there should be some measure of intellectual sympathy which will reach its height when man and wife work together with some large ambition. No doubt there are some matrimonial voyages on crafts which have only two sails, and others which have only one, and others which have none, and are only at the most legal marriages; but the happy married life is the one with three sails—organic fondness, esthetic attraction, and intellectual sympathy. After married life has lasted some long time there comes a dangerous period—although all the periods are dangerous, since each has risks as well as promises. But in later married life there comes a particularly dangerous period of life, when the sex urge has waned, say, after fifty or sixty. What is one to say about that dangerous period of life for man and woman, disquieting to so many? Well, two things, frankly and sincerely. The first is the grave danger, even for some of the best of us, of artificially fanning fires which should be smouldering—an undoubted danger for men especially. Secondly, common sense suggests that this period after fifty, when the sex life has largely waned, should be anticipated, and provided for by the cultivation of hobbies and enthusiasms, something to occupy life, especially as the strain of activities has usually begun to lessen at the same time. It seems that we educate too little for leisure time and too much in reference to the workaday world.

AGEING.—Yet why should people necessarily age? The Protozoa

seem to be immortal; the Amœba never dies a natural death; and perhaps there are some very simple many-celled animals which never grow old; but all the higher animals age. Why should this be? The answer given by the most profound student of the subject, namely, Prof. Child of Chicago, is that what happens is a slow accumulation of unrecuperated arrears of wear and tear, effects of fatigue, which are not made completely good by food, rest or sleep. All through life there is a contest going on between the processes of rejuvenescence and senescence, and for a long time rejuvenescence is well ahead. With plenty of food, rest and sleep, rejuvenescence has its innings. But slowly the tortoise creeps up on the hare and senescence begins to gain on rejuvenescence. Inside the cells, especially in what one might call crudely the framework, there are fatigue effects which are not made good, especially in the hard-worked organs, such as the liver, kidneys, heart and brain, to put them in their proper order, for the brain relatively seldom suffers from overwork. In all these hard-working organs the colloidal intra-cellular films, which separate the living matter into areas, undergo wear and tear which is not perfectly recuperated. In other words, it is not the living matter which gets fatigued; the furnishings of the laboratory are worn out. It is probable that ageing is due to the accumulation of unrecuperated wear and tear in the colloidal framework of tissues and cells. Of course many men do not age at all, but their life ends in various ways which are just worth recalling. A man may die before ageing through an accident; or because of some virulent microbe; or he may die from some malignant growth which still largely remains a mystery; or he may die from over-eating, over-drinking, or over-anxiety—all producing toxic effects which end in death; or it is possible that he may die from some badly deteriorating environment or occupation. Relatively rarely does he die from overwork, though this is common among bees.

But suppose man weathers all crises and passes into senescence, what in the name of Biology can we say to him then? Usually it is too late: but, especially if he has been biologically trained, he may have anticipated to some extent this senescent period. We use the word "senescence" for what is normal, and "senility" for that kind of ageing in which disintegrative processes have begun to occur in the body. The advice from the biologist's point of view would be to avoid bad debts due to bad habits. Senescence is more likely to be pleasant when the man has avoided certain kinds of arrears. Secondly, that he should cultivate hobbies and interests for this ageing period; for example, he might then begin to play golf or to geologise, and thus have a new interest for the senescent period. Moreover, he should cultivate positive rejuvenescence, if he can discover the line that is suitable for him. He should join the Order of the Old and Bold and find in the evening of life a joyous time.

To avoid bad debts, to have hobbies, to cultivate new interests, to make a new effort towards positive health—these are the ways to prevent senescence becoming senility.

So we see that we must cultivate health of body and mind with renewed enthusiasm, so as to make the most and the best of every stage in the trajectory which is so full of promise and yet so full of risks.

THE PROBLEMS OF POPULATION

This subject of population, biologically regarded, is so difficult that no apology is needed for putting what we have to say in the somewhat unusual form of a series of questions and answers.

What is the population of the earth? The population of the earth is about 1,750,000,000—though, of course, the census in some places, such as China, is not very reliable. *Is the world's population increasing?* The absolute increase every year in the world's population is about 12,000,000; some put it at about 14,000,000, some at 16,000,000, some as high as 20,000,000; we are quite safe in saying that it is about 12,000,000 per year. This is an astonishing fact when one remembers that Malthus, who lived about the time of the French Revolution, stated that the population of the world was then 850,000,000. Thus the population of the world has doubled since the date of Malthus. Suppose that mankind has been in progress for half a million years! Millions were born and millions passed away; yet the portentous fact is that the living population was doubled in the last hundred years.

Is the absolute increase in the world's population equally distributed? Very far from it. In the period between 1800 and 1910 the increase in population in Russia and the United States, for instance, was prodigious. During the same period the population in Great Britain was trebled, an increase enormously greater than that of some other European countries, such as Portugal. With regard to the United States, one must remember that the total was swelled by the tide of immigration.

In the period from 1906 to 1926 careful inquiry into the statistics of increase of population showed that if the rate of increase during that period was maintained France would take 436 years to double her population. On the other hand, in Canada, where the increase was more rapid than in any other country, the population, if it went on at that rate, would be doubled in twenty-four years. England has doubled her population in sixty-seven years, and Germany in fifty-one years, and so it goes on.

We must consider the international aspects of the population question as well as the national and family aspects. A very interesting

inquiry is how this unequal increase of the population relates to colour. The following figures are impressive:—

	Total in Millions.	Annual Increase in Millions.	Annual Increase per 1,000.
European white ..	650	7·8	12
Non-European white ..	60	0·48	8
Brown	420	1·05	2·5
Yellow	510	1·53	3
Black	110	0·5	5
Total	1,750	11·41	30·5

The whites in Europe, or of European origin, with a total of 650,000,000, show an increase of 7,800,000 per annum, and that means 12 per thousand. We may almost neglect the non-European white races—60,000,000, with an increase at the rate of 8 per thousand. The brown races, with a total population of 420,000,000, increase at the rate of 1·05 millions per annum as against the white 7·8; the yellow, with a total of 510,000,000, show an increase of 3 per thousand; and the black races, for instance, of India, with a total of 110,000,000, increase only at the rate of 5 individuals per thousand. Now these added up give the total of 1,750,000,000, and the average increase per annum is 11·41 millions every year.

What is the relation between the increase in population and colour? The rate of increase is highest among the white races and lowest among the black. And why should the whites increase so enormously? The answer is not far to seek. Because they rule more than nine-tenths of the world's surface, and use their political power more effectively than any other race. On this the enormous lead of the white races most depends.

Is the birth rate increasing or decreasing? In 1850 the birth rate in Great Britain was about 32 per thousand—an enormous birth rate from our present point of view. The birth rate is less to-day, only 24 per thousand. The climax came in the mid-Victorian period, 1876, when the maximum for Great Britain was reached—36·3 per thousand. It has fallen from 36 to 24 since 1870.

The decline of the birth rate is common to all European countries, except Russia and the Balkans. It is more marked in some than in others. The birth rate depends on many variable factors, and the subject requires very careful handling. For instance, unless one relates the birth rate to the number of child-bearing wives under forty-three the figures would be extremely fallacious.

When the crude birth rate decline is corrected in reference to well-known conditions of increase we find a remarkable variety in

the different nations. The birth rate has declined most in New South Wales, next in Victoria, next in Belgium, next in Saxony, next in New Zealand, then Germany, then England, and France last of all. To the question, then, is the birth rate increasing or decreasing? the answer is: decreasing in all civilised countries except Russia and the Balkans, but decreasing at different rates in the various countries.

How can the population be increasing if the birth rate is decreasing? Obviously, because the birth rate is at present far in excess of what is needed to compensate for the death rate. The white race has probably an excess of births over deaths of from 12 to 13·5 per thousand annually. And not only is the birth rate in excess of the death rate; one must take account of preventive medicine and hygiene, agencies securing infant welfare, and so on. For these are gradually lowering the death rate, especially in very early years.

How many acres would each of us need to keep going? That is the vital question. No doubt in an island country like Great Britain the supply of fish food is enormously important, but it is not important in relation to the world as a whole; and, as far as we can judge, the exploitation of the sea, even with a very optimistic outlook on fishery problems, has to-day somewhat narrow limits. The exploitation of the sea will not suffice to keep the wolf from the world's door, and we need not refer in detail to mutton and beef, eggs and poultry, since these are all just reincarnated grass. Sixty per cent. of the world's population are living on "grass", or on cereals which are grass, and the question is how much "grass" the world will yield us. The answer involves a very interesting calculation which has been made by various experts, such as Profs. East and Pearl, with great care. In the world at present, if we exclude the Arctic and Antarctic regions, there are 33,000,000,000 acres of surface, but of these only 40 per cent. are arable. So we must reduce our available area at once to 13,000,000,000 acres. What we have to divide up among ourselves is 13,000,000,000 acres of arable ground. Now it seems fairly certain that every man and woman of us requires as a minimum 2·5 acres to live on, $2\frac{1}{2}$ acres to live on without a cow! If 2·5 acres are needed for each individual, we have to divide the total number of available acres by 2·5, and that gives the maximum population which the world will comfortably hold, and the answer is 5,200,000,000 individuals as the probable total. It is a curious thing that several of those who have worked at this problem from a different point of view have estimated the total number at not less than 2,000,000,000. The maximum estimate was made by Penck, who suggested a possible total of 8,000,000,000. If we add these two estimates and divide by two, we get 5,000,000,000 people as the world's maximum comfortable population. No doubt there is a good deal of uncertainty. Thus some much more effective methods of

agriculture may be discovered, but there is no immediate prospect of an enormous improvement. No doubt, again, people can live comfortably now where they did not think they could live comfortably before, in places like Alaska, for instance; but all that has been allowed for.

Some optimists are always saying that some great biochemical discovery will change the whole problem of human nutrition, but this is only an off-chance! As far as we know, there is strong probability that we must look out for the earth's saturation point being reached at about 5,200,000,000 individuals, and at the present rate this figure will be reached in a little over a century. That is a fact that gives one pause.

But will the population ever reach the limit? There is some reason to answer in the negative, for in individual countries the limit has seldom been reached. This is due to a law, to speak metaphorically, or to facts that are formulated in a law, that as the density of a population increases there comes an automatic check on further increase. The population curve worked out by Raymond Pearl is something like a letter S made of copper wire, straightened out at the two ends, a curve with an upper bend to the right and a lower bend to the left. In individual countries, as the limit of population has from time to time been approximated to, a decline has set in or a crisis has occurred which has greatly reduced the numbers.

But what we have to look forward to is reducing the population before the saturation point has been reached. That is the crux; to bring about a reduction so that the stationary population will be a population in relative comfort like that of France—happy on the whole—and not in a position like that of China of to-day—overworked on the whole. And it is for science so to direct things that the reduction of population comes about before the *débâcle* of the 5,200,000,000 crowd.

Is the falling birth rate general in any country? The answer, unfortunately, is No! The decline of the birth rate is differential; it is unequal in different sections of the community. In all countries farmers have more children than philosophers, and miners have more children than millionaires. In some cases there is least decline where it is most wanted; the wrong kind of people have too many children, and the right kind of people have too few—that is the lamentable fact. In England and Wales out of a hundred couples of, say, teachers, what is the average number of children? Only 95! —which is lamentable. A hundred couples of clergy leave progeny from 96 to 101—96 if they go to chapel, 101 if they go to church. That is to say, if you seek through 100 couples among the clergy, the residue of offspring is between 96 and 101, about one for each pair. On the other hand, when you come to miners, who are a

splendidly healthy set of people on the whole, the number is 258 per 100 couples, and that is not unsatisfactory from the biological point of view. But among general labourers the figure is 438 per 100 couples; the average family being thus over 4. Prof. Raymond Pearl has collected some statistics for America, and though his total numbers were small, his data were very accurate. He gives this little table:—

Families of farmers	5·92
Families of teachers and professors	4·89
Families of merchants, doctors and lawyers ..	4·82

The farmers' families showed an average of 5·92 children, while teachers, with professors thrown in, had an average of 4·89 per family. The average family of the general professional class, merchants, doctors, lawyers, Congressmen, and the like, was 4·82—a more hopeful set of statistics than has sometimes been given for the size of the family in North America.

Why is there this differential fertility? Herbert Spencer gave an interesting answer which is probably somewhat misleading. He said there was a physiological nexus between individuation and the rate of reproduction; that is to say, the more individuality, the more culture, the more morality, the more mentality shown by the individuals the less would be their rate of reproduction. The tapeworm has 8,000,000 eggs, while the golden eagle never lays more than two a year. The golden eagle has a very high individuality with a low rate of reproduction; the tapeworm with its degenerate body has an enormous rate of reproduction. And so with other types. If we understand Spencer aright, he thought that there was a direct physiological nexus between individuation and the rate of reproduction. But what one sees in the animal kingdom may be interpreted as follows: when a type of animal varied approximately at the same time in two different directions, namely, (*a*) towards increased cerebral capacity associated with increased parental care, and (*b*) towards decreased or economised reproduction, then there came about an adjustment towards small families. Thus birds advanced greatly in the direction of intelligence, sympathy, and parental care, and, having varied greatly in that direction, they were able to afford to take advantage of a variation in economised reproduction.

There do not seem to be many facts to bear out the idea that individual improvement in intelligence or education or morals will have *ipso facto* any direct physiological effect on the fertility, though this was one of the arguments used many years ago against the higher education of women. It was said that heightened individuation would reduce their fertility and cause decreased reproduction—

and that was in consonance with Spencer's theory. But this argument requires physiological and experimental vindication.

If there be not this direct physiological connection between individuation and rate of multiplication, what is the cause of the differential fertility? The causes are no doubt multiple. It surely depends, in part, on the conditions of housing, for in many of the working-class houses there is a maximum of temptation and a maximum of opportunity for sex gratification. And then among the poorer folk and the more hard-pressed as regards physical work, there often tends to be, on the whole, a restriction of human interests, and therefore a tendency to become preoccupied with the things of flesh. Possibly, though one must walk carefully here, there is in many of the humbler folk a lack of the control factor, not that this deficiency is not marked enough elsewhere. Very important is the tradition of women's freedom and a realisation of the wisdom of giving them a full life, and it may be that this idea is less current among the working folk than among the better educated. Many factors such as these have tended to bring about differential fertility, but one must carefully notice that high fertility in itself is not to be regarded as an indication of social or intellectual inferiority.

Why should we be afraid of this differential fertility? Because, according to Pearson, 25 per cent. of the present generation beget 50 per cent. of the next. And if a large fraction of that 25 per cent. consists of types who are rather towards inferiority, then so much the worse for the next generation. On the other hand, suppose one can discount the lowest 10 per cent., for the reason that mortality is very great amongst them, and suppose one can discount the uppermost 10 per cent. who multiply very slowly, one would be left with 80 per cent., who, after all, do not differ very much amongst themselves in physique and mental ability. On the whole, it is the mediocre folk who are carrying on the world's work, mediocre but yet sound and fresh, and therefore we must not be unduly afraid of the differential birth rate as long as we can rely on a fairly sound 80 per cent., or perhaps it should be 75 per cent., from whom, if we read history aright, geniuses and artists have mostly come.

Why did the birth rate so extraordinarily rise and fall in British history? In the nineteenth century the population of England and Wales was more than trebled—one of the biggest biological facts that we know. The population of England and Wales in 1801 was 8,893,000; in 1901 it was 32,528,000 adults; it had more than trebled during the century. Why was that? Because of the great increase in material prosperity, which tends to lessen man's grip and to lessen his restraints. But while a great many people during that period of industrial prosperity were enjoying material well-being to an extent previously unprecedented, there were under this what Havelock Ellis calls "circles of Hell", where the proletariat were

multiplying recklessly. Another reason was that about that time preventive medicine first began to make itself felt in reducing the death rate. Furthermore, as "Clayhanger" brings out, it paid to have many children when they could be sent early to the mine or the factory. It paid to have a lot; and to that unworthy feeling of the parents, that the more children they had the better, the employers said, naturally enough from their point of view, "Amen!" Those who have gone deeply into Natural History on this line assure us that foxes quite approve of large families among the rabbits!

So the population rose extraordinarily. *And why did it fall?* That again is a very intricate and complex question with many answers. One must take account, for instance, of the age composition of the community, trying to find out how many wives under forty-five there were during that period, and how many husbands under fifty-five. In other words, one must inquire into the age of marriage and the duration of marriage, and, if possible, into the tradition of loyalty between husband and wife, and into the amount of illegitimacy, and into prudential and artificial birth control, and perhaps there is something beyond all that—an obscure law which has not yet been worked out for mankind.

A fertilised egg cell, such as that which gives rise to a sea urchin, divides into two, then into four, eight, sixteen, thirty-two, and so on. It multiplies itself at first quite slowly, but after a while the multiplication of cells is so quick that we cannot keep count of them. By and by, however, the multiplication of cells begins to slow off—in some organisms much more quickly than in others, and in some organisms more slowly than in others. Among mammals the multiplication of nerve-cells stops at birth. There is a decline till there is no multiplication at all, a stationary condition of cells. Pearl's population curve applies to the multiplication of cells in the building of the body. Similarly, if yeast cells are placed in a suitable solution they begin by multiplying rather slowly; soon they increase very rapidly, then the rate decreases and the curve wanes away, till finally the cells cease to multiply at all. The same curve is illustrated by fruit flies battening on bananas in a jar; and Pearl's contention is that the same curve applies to man as applies to yeast cells, or to the hens in the poultry yard, or to the multiplication of cells in the development of an animal. In his book on the biology of population, Pearl goes very thoroughly into the interesting case of Algeria, where there are censuses available for seventy years, and he has found that the facts fit the curve most beautifully. Algeria is a particularly good case to take because there is no complication of the problem by birth control, and the public health service, though not to be despised, has not begun to have any very powerful influence. It is probable then that this population curve expresses a

genuine law of population if we could only translate it into the concrete.

As the density of an animal population begins to be very marked, a check to further multiplication steps in, and we can understand that automatic check because it means less food. The density of the population has so increased that there is less food available, and not only less food but less space to move about in. Pearl found that the space at the disposal of the hens in his poultry yard made a great difference. And it has been shown for various ranks of animal life that the check put by the density of population on further multiplication can be understood in terms of reduced food, lessening space, and the accumulation of toxic waste products. Especially when the animals are aquatic is the accumulation of toxic waste products in the water an important factor. And without pursuing the subject further at present, we may say that biologists are beginning to understand why there should be an automatic check when a certain density of population is reached.

But what about man? Whenever we think of man we see that for civilised countries density of population cannot mean the same as among animals. Among animals density of population usually implies scarcity of food, but man is not entirely dependent on the area in which he lives. Indeed, it may be easier to feed people in a crowded urban area than in a sparsely populated rural area. Thus density of population does not mean the same thing for mankind as among animals. Among animals the number per acre would at once affect the food supply; in man this need not follow except in primitive rural conditions. In fact, everything points to the conclusion that the decline of the population rate which occurs in mankind is not due to biological factors except to a slight extent; it is due to psychological and other factors of a subtler kind.

What is to be said for the restriction of the size of the human family? In the animal kingdom the restriction of the family is always associated with increased parental care and affection. So that is a good lead. The lesson to be drawn from the reduction of the animal family is that it tends towards a higher pitch of life, more parental care, more affection, more family life in the true sense. Here is a suggestion of the benefit that might follow a restriction of the size of the human family: there would be more parental care and a better send-off in life; there would be greater freedom of life for the mother. A reduction of the population rate would also work against war, for most wars have been due to over-population. It would always be working against the *débâcle* that will be involved if the world becomes over-full. Moreover, if the family were in process of greater restriction than at present, more attention would be paid to the serious problem of the entailment of defects. If people were deliberately restricting their families, they would be a little more

apprehensive as to the consequences of a reckless perpetuation of those who are in some way or other defectives.

What is to be said in regard to artificial means of birth control? Our previous question was what benefit might be looked for through a restriction of the size of the family; now the question is what can be said for or against so-called artificial birth control? No time should be wasted over the word "artificial"; it is quite futile to make a bogey of that idea. Civilised mankind is now "artificial" through and through. Does anyone object to artificial respiration for a man nearly drowned? Does anyone object to the use of thyroid treatment for a child with a defective thyroid gland? Does any one object to the artificial use of serum against diphtheria? The objection based on artificiality will not work at all. It is an unfair argument.

Much more worthy of consideration is the objection that the use of artificial means of birth control will make it easier, for those so inclined, to have sex indulgence without responsibilities, and will make it easier, for those so inclined, to have anti-social sex relations without any social punishment. This is, obviously, a very serious objection; but can one really believe that the type of person who is constitutionally much inclined—of course, anyone may be swept off his feet—to that sort of thing will be restrained at present by any considerations at all? If ethical considerations are not habitually influential in the individual life, then "damn the consequences!" expresses the animal surrender to the sex-urge. Another objection is that the artificial use of contraceptives or some other method is inartistic. It is undeniably a sort of mechanical incursion into a sphere where one feels that passion and impulse should be allowed a legitimate freedom. We cannot answer this objection, except that the inartistic method may be worth while for the gain that may result.

Prof. Pembrey, a distinguished physiologist, has spoken very strongly against artificial birth control, and his arguments must be considered impartially and quietly. His chief point is that artificial birth control methods will lessen the struggle which engendered moral fibre and strength of character in the past. His idea is that prudential and ethical restriction has engendered the moral fibre of our folk. It is not very clear how there could be much so-called ethical restriction without moral fibre, and if it be said that the practice of sex restraint has *increased* the moral fibre, it does not seem inconceivable that the moral fibre might be increased by discipline in other directions.

It is often said that artificial birth control is immoral. But what is immoral? We must bear in mind that this practice, if it is to become general, has to be deliberate, not random; and an action that is thought over and resolved upon is never quite immoral.

On the contrary, it has an ethical note; it has been resolved upon and decided upon as the best thing to do in the circumstances. It is far more moral to practise birth control than to say "damn the consequences!" On the other hand, it may be said that the use of artificial methods of birth control will tend to increase the proportion of inferior stock, because the methods will be least used by the less educated, the less intelligent, the less moral. Yet for how long would these less educated people continue to refrain from the use of birth control methods? How far does the slight knowledge which has already been gained from the clinics justify the assertion that they will not use them? All these changes work slowly from above downwards. As a matter of fact the use of birth control methods among the very poor was more than begun long ago.

What is to be said for the so-called artificial methods of birth control? First of all we must keep our eyes on what will happen if the world becomes too full. Is not the birth control method the least dangerous, the most practicable way of evading a terrible *débâcle*? People say, "Practise sex temperance, practise sex restraint." But in present conditions of housing it is nonsense to tell the husband to practise temperance and control beyond a certain limit—men are not angels, as is evident. One must not credit them with supernatural powers of self-restraint, and in many cases the more temperate the parents are, the more certain they are to have children. They cannot be temperate beyond a certain point, and their self-control increases the likelihood that when they come together there will be a child.

Again, in answering objections one may urge that the method of artificial birth control will obviate to some extent the disastrous postponement of marriage with all its far-reaching evil consequences, and will increase the facilities for early marriage with its possibilities of progress and happiness. We should lay great emphasis on this especially, that for the poorer folk artificial birth control methods will allow the mother greater freedom of life, better health and more joy in her children. Perhaps this is the strongest argument of all. How terrible it is to hear over and over again, "I had ten children and two are left." Anything is better than this common tragedy. We should face some risk to put an end to that sort of thing.

If it is true that we are moving rapidly towards the saturation point in the world's population, a humane effort must be made to arrive at a stationary population before the extreme evil consequences are within sight. We must seek to secure restriction of the size of the family before we are in sight of the terrible struggle for existence which will ensue in some form or other if the rate of population-increase continues as at present.

Everyone has sympathy with those who would say: "What a repulsive frame of mind always to be weighing *biological* considerations!" But perhaps the biological pre-occupation is as good as any

other pre-occupation. In any case it is indispensable. To be always thinking of these things in their biological aspects is repulsive to some, only because it is so new. We have not got accustomed to it; it is unusual. Many of our fellow-citizens look at everything *sub specie æternitatis*—under the category of eternity—but that does not prevent them from being very pleasant comrades; and all a biological attitude means is looking at everything *sub specie vitæ*—under the category of life. But evolution is a slow business; and in regard to birth control, time may not be ripe as yet for urgent propagandism. Yet it seems to us that the time is ripe for giving reasoned statements, and for giving, to the poorer people especially, opportunities for expert advice when their physicians or they themselves think it is needed. Parents or would-be parents should at least have *opportunities* for the best expert advice.

Yet after all, when all is said and done, and one goes out into the open air, one feels that if one loses the chivalry and tenderness of lovers, the joyousness of the springtime of the heart, the adventurousness of early marriage, the delight in having children with whom we are young enough to sympathise and play, we are losing some of the most fragrant flowers in life.

PRACTICAL APPLICATIONS OF BIOLOGY

The idea of utilising science for the amelioration of life is relatively modern, except as regards medicine. For even the fundamentally important pre-historic domestications and cultivations were probably very different psychologically from the present-day deliberate utilisation of biological science for the control and improvement of man's practical relations with living organisms, both plants and animals.

Man's circle of practical interests intersects the life-circles of so many other creatures that we cannot here do more than map out the territory. Beginning with animals, we may follow an arrangement suggested many years ago by Sir Ray Lankester. First, there are those wild animals that are captured for food, and it is part of the business of economic zoology to make the most of them. Their exploitation, as in the case of fisheries, must not be short-sighted, but must take account of the intricacies of the web of life. Here one thinks of deer and antelopes, rabbits and hares, pigeons and partridges, frogs and food-fishes, squids and snails, cockles and mussels, oysters and clams, crabs and lobsters, shrimps and prawns, palolo-worms and sea-cucumbers. Every year, except in cases where man is shortsighted and greedy, there is some improvement in the exploitation of animals used as food, not only in trying to secure a steady supply, but in making the most of what is captured. Thus there are

improvements in the state of the immense quantities of trawled fish brought to market.

Second, there are those animals captured not for the sake of food furnished directly by their flesh, but for the sake of other products, which are often not edible. Here are included baleen whales, elephants, beavers, birds of fine plumage, crocodiles for leather and turtles for combs, inedible fishes for glue and manure, oysters for pearls, and beetles for blisters. In one of the halls of the Oceanographical Museum at Monaco there is an almost startling exhibition of the variety of uses to which man puts the spoils of the sea. This utilisation goes on apace.

Third, there is the short list of animals that man has more or less domesticated because of their direct or indirect utility—such as dog and horse, sheep and cattle, goats and reindeer, pigeons and poultry, ostriches and pheasants, silk-moths and honey-bees. Here the modern biologist has to advise in regard to the application of genetics to the improvement of breeds. Already for animals, as well as for plants, the applications of Mendelism have worked wonders.

Fourth, there are the animals that favour man's operations, like the earthworms that have made the fertile soil and the flower-visiting insects that secure cross-pollination. Here the main service of the economic biologist is to disclose and appreciate the vital linkages that bind living creatures into an intricate system. Success in preserving the long-established Balance of Nature depends very largely on a sound knowledge of inter-relations. Ignorant eliminations and introductions have proved very costly. But now man is learning to play a *positive* part in preserving the balance, e.g. by introducing an Australian Ladybird beetle to counter the ravages of the Australian Fluted Scale-insect in California, where it was destroying the citrus trees.

Fifth, there are man's animal enemies, reduced in modern times both in numbers and size. Most of the beasts of prey have ceased to be important, save as yet in India, where they not so long ago were destroying some 20,000 lives annually, and where also as seriously the poisonous serpent still bites man's heel. Of far greater mischief, however, are man's parasites, such as hookworm and bilharzia; and also the vehicles of parasites, such as the malaria-carrying mosquito and the sleeping-sickness-carrying tsetse fly. The biologist has here both achievements and remaining tasks in unravelling life-histories and discovering checks.

The sixth group is composed of animals which injure man indirectly, by attacking organisms that are useful to him, notably his animal stock and his crops. The list includes voles, wood-pigeons, worm-parasites, locusts, cockchafers and cotton-weevils, wheat-midges and warble-flies. It is part of the task of the economic

zoologist to combat these injurious animals, both directly and by encouraging natural checks. He has also to advise against operations that upset the Balance of Nature and against careless importations and transportations.

Seventh, there are animal enemies which injure man neither directly, nor through his stock and crops, but by getting at his stores or permanent products. Termites are very destructive in warm countries; rats and mice spoil much more than they eat; weevils and their relatives destroy stored corn; boring beetles eat away the rafters; ship-worms and boring crustaceans do much harm to wooden piers and the like. All these have to be coped with.

But an eighth group consists of animals that are man's indirect friends, by keeping a check on the fifth, sixth, and seventh groups, and must therefore be conserved and encouraged. Above all, birds keep down insects, and so help agriculture, abate malaria, and so on. Thus owls keep down the voles; lapwings feed on wireworms and leather-jackets; hedgehogs crunch slugs, and toads are also friends to gardeners; ichneumon-flies lay their eggs in caterpillars; spiders catch many injurious insects; ladybirds levy toll on the green-flies; water-wagtails are fond of the small water-snails that harbour the larval stages of the liver-fluke; and so on through a very long list. Yet in truth the chain is endless, since there are species inimical to this eighth group, and so indirectly to man; and these in turn have their enemies

Similarly for plants, there are wild species directly used for food and drink; those that furnish valuable products like textiles and drugs; those that have been cultivated; those that help man, as forests do in improving the climate. On the other hand, there are inimical plants like the "poison-ivy", and many bacteria; the weeds that become pests and the moulds that attack crops; the fungi that destroy stores and dry-rot wood.

The central idea of economic biology is that the circle of human life intersects or is intersected by many other circles; and these intersections, which are often changing, have to be controlled in man's interests—these being generously and farsightedly interpreted. Man is part of a web of life, in the weaving of which he increasingly shares; and the success of his weaving depends on his understanding, which in this particular case is expressed in Economic Biology, which we have here to leave to volumes of its own.

There is reason for encouragement in the multiplication of societies, laboratories, and journals of Economic Zoology and Botany, not forgetting Economic Biology in the stricter sense; and while the practical gains are already great, there has also been a welcome enrichment of the so-called "pure sciences" at the hands of those who have been largely pre-occupied with concrete problems.

IN ILLUSTRATION: THE CONQUEST OF DISTEMPER.—A dramatically clear instance of the biological control of life is the discovery which Messrs. G. W. Dunkin and P. P. Laidlaw have made that dog-distemper can be baulked by a vaccine treatment. The troublesome and costly disease has been a shadow for many a year; but man seems to have conquered it at last. For a long time it has been recognised that distemper is a microbic disease, somewhat analogous to measles and scarlatina in children. While predominantly catarrhal, affecting the lining of the nasal passage, it may spread to the lungs and the food canal, the liver and the nervous system. It is particularly common in puppies between four and eleven months, but increasing age does not give any complete protection. An attack in early life usually confers immunity if the animal survives, but this is by no means absolute. The general treatment in the past has been to administer internal disinfectants and to try to keep up the patient's strength, though by means of very light food.

One of the reasons why distemper has baffled investigators for so long is that the disease often occurs in conjunction with other microbes besides the specific one. In other words, there may be a mixed infection. The second reason is that the distemper microbe is much smaller than an average bacillus. It belongs to the elusive series of "filter-passers" or filterable viruses, including, for instance, the causes of smallpox, rabies, foot-and-mouth disease, and, according to some authorities, measles and scarlet fever. There are also many plant diseases that are due to filterable viruses.

In 1926 Dunkin and Laidlaw showed that a pure form of distemper could be produced in ferrets infected from dogs. It can be transmitted from dog to ferret, from ferret to ferret, from ferret to dog, by material in which no bacteria can be demonstrated. In their further experiments at the Medical Research Council's Farm Laboratories at Mill Hill, the investigators prepared from infected ferrets a vaccine that immunises either ferrets or dogs. A convenient form of the vaccine is a formaldehyde extract of the infected ferret's spleen; and a large dose of this non-living vaccine will induce immunity in about 90 per cent. of the ferrets into which it is injected. But to consolidate the immunity thus induced, it is necessary to administer living virus. It is probable that what is brought about in the dog or the ferret is some general change in the cells of the body, and not the production of some specific anti-body or counteractive in the blood. The triumph is that dogs may be rendered immune to a common and vexatious disease, and that a single dose may be enough. A dog first treated with the formalised extract from the tissue of a distemper dog, and subsequently with living virus, appears to have acquired solid long-lasting immunity, firm against other strains of dog-distemper. The investigators deserve the heartiest congratulation. The next step is the large-scale production of the immunising

vaccine, but that, though requiring meticulous carefulness, is not a task for investigators as such.

THE KINGDOM OF MAN

We continually hear, and very rightly, of man's conquest of his kingdom, a conquest in which the torch of science is his most effective weapon. We are asked to admire, as we do, such achievements as aviation, broadcasting, capturing the nitrogen of the air, and it is easy to continue the alphabet; yet there is reason to be also astounded at man's slowness to enter into his kingdom. Especially as regards the control of animal and plant life, it often seems as if a relapse into easy-going ways comes as the nemesis of every advance. Or is it that the powers that be have not imagination enough to realise what new wealth lies not far from our doors—waiting the investigator's "Open Sesame"? In regard to the conquest of disease, there has been some far-sighted generosity of endowment, but as regards the fresh exploitation of plants and animals how little! No one supposes that first-class makers of new knowledge are as common as blackberries, but fifty could probably be found in Britain, whom it would be cheap for the nation to employ at such thousands for salaries and equipments as they could vitally and usefully employ. A short time ago the sum of £20,000 was given by the Empire Marketing Board to Kew Gardens for botanical research, and so far well. But ten times that, among our botanic institutions, would not be too much. For it would rapidly "pay" by increasing the national wealth, as the following quotation from a recent article forcibly suggests, "Why within the Empire are we growing canes with fifty per cent. lower percentage of sugar than others that are available? Why are we allowing the prosperity of New Zealand to be arrested by the multiplication of earwigs and the spread of the blackberry—two pests against which a remedy has been discovered at Rothamstead? Why do we cut down forests (and thereby induce floods) for the sake of paper which might be manufactured out of annuals? Why are we so prone to suppose that we have exhausted the resources of the plant world? We may at any time repeat the economic revolutions produced in the world by the wheat, rice, cotton, and rubber plants. The amazing 'black boy' weed of Australia awaits exploitation. There are plants ready to hand which would change agricultural methods as the turnip did." If all this is true, why are we not more impatient?

As to the public need—not simply of fuller information, but of comprehensively social and even moral arousal to the scientific viewpoint as fundamental to the practical—a vivid illustration may be taken from the newspaper before us, one of the best in London.

On one column (with three lines of large capital headings, evidencing a sub-editorial recognition of importance), we read THE MENACE OF MALARIA—ROSS INSTITUTE'S FIGHTING PROGRAMME—CONTROL MEASURES—followed by a brief, but intelligent report of Sir Malcolm Watson's opening discussion at the Ross Institute's Industrial Anti-Malarial Advisory Committee. In this he indicates various practical measures, as for dealing with different types of jungle, streams, etc., and also the need of getting estate doctors, managers and engineers, etc., to come to the Ross Institute when on leave, and learn what can be done to control malaria. And this not only by getting advice, but even in qualified cases with free facilities to use the research laboratories. And he points out how it is only within the last seventy years that malaria has spread in a severe form in Western and Central Bengal; and Bengal will soon follow the way of Ceylon (of which two-thirds is now uninhabitable on account of malaria) if something be not done soon to control this.

So far well: here is awakening at last to one of the grave world-crises (and one of the most plainly intelligible causes of "unrest" in such regions). But now pass to the correspondence column of the same paper, with two letters under the heading of "Italy and the Mosquito", and those offering precautions and remedies. "The best remedy I know for a sting is to hold a lighted cigarette as close to the place as possible without scorching the skin. The heat kills the microbes which have been injected by the insect." "Another correspondent has suggested that the eating of garlic by Italians may render them immune; but I have always found that after staying in a foreign country you become more or less immune." A following letter offers mild precautions—such as burning a "Fidibus" at bedtime. Does not such well-meaning correspondence bring out the absence of knowledge, even among those who have had personal opportunity? One of us lately spent most of ten years in India, and in town-planning or teaching was never far from this almost everywhere more or less pressing question; so must mournfully record that—apart from its very few British and Indian specialists really competent—he could find little knowledge, or practical response among governing authorities, British or Indian, for whose city improvements he was engaged, and otherwise by no means so discouragingly. It would seem as if to the traditional education—British or Indian here matters not, since alike without adequate initiation to biological science—there were added that further apathy which has been seen, since Plato's time, to be so commonly associated with that long persistent and deep-lying malarial infection which so few escape.

Yet malaria is not the only instance: the same preponderant public immunity to biologic science and its teaching persists all round, and in Europe as well as India. When Lister's antiseptic

revolution, in hospitals and their cases alike, was fully going in Edinburgh (though then in London scoffed at as "the Scotch fad"), Pasteur sent him a bright young French Army surgeon to learn his technique. On July 4, 1870, he was recalled by telegram to the French war-front; so spent the hours before train-time in buying up a goodly outfit of antiseptics and dressings. But on reaching the front, and unpacking his treasure-load, his medical chief said, "What's the good of this! Send it back to Paris!" so condemning his soon abundant wounded. In the Boer War, in which the death-rate of our troops so vastly exceeded that from Boer bullets, public feeling caused the sending out of an eminent non-military surgeon, Sir Frederick Treves, whose report is still remembered as describing the Army's medical outfit as but "of archæological interest". But in the subsequent Russo-Japanese War, all then known scientific precautions were taken by the Japanese, for wounds, drinking water, etc., and even to the soldier's washing not only himself, but his shirt also before action, so assuring him ready convalescence from a clean and properly treated wound, while the Russian too often died of a dirty one. Thus, in fact, it was not until the Great War—a full generation and a half after Lister's clear demonstration of war's need of cleaned wounds, and yet longer after Pasteur's of its need of clean water, that there was medical and surgical efficiency more or less on all sides (though least so on the Russian), and thus even more millions saved than those killed.

Take again the current slum-clearing movement, now at length actively awakened—forty or fifty years after its needs were seen, and even its methods were demonstrated. But even now, see how many a substantial old building, quite capable of sanitation and repair, is condemned by the rough-and-ready inspection of municipal committees, or even their engineers, from its being undeniably repugnant at first sight, as dingy and smelly too; but too much in ignorance that really poisonous germs are inodorous, and that nothing that smells badly, outside or in, but could be removed—of course along with the really pernicious germs too, and yet more easily—in course of cleansing, sanitating and draining, ventilating and whitewashing; and thus often renewing, easily and economically, its old pleasing aspect, and even enhancing this: while if it still interferes with the straight lines nowadays so wastefully pushed to excess on the plans of nearly every improvement scheme, that is often so much the better—not only for beauty, by relieving their mechanical monotony, on the whole still increasing—but also for homeliness within, and without also, since affording corner spaces within which children can safely play, and elders sit, and both can sometimes even garden. In such ways—speaking with experience from Scottish and Irish as well as English towns and cities to Indian ones, and of many between—it is not only possible, but easy, given

moderate planning skill, in any moderate-sized town, often to save thousands, up to many tens and hundreds of thousands in larger cities, and even to millions in a metropolitan one—thus more tens of millions in the national aggregate than the reader could readily believe, till he has some of their plannings and their re-plannings, —the conventionally wasteful and the revised—clearly set before him. Is it asked—how does one know this?—or—what has this to do with science?—the united answer is plain—that of the best part of a lifetime's experience of such work, and this directly inspired by the "conservative surgery" of the hospital, and its own cleansing; so thus readily extended to cities by dozens, and from cold temperate to tropic lands.

Yet another example of how our existing scientific and technical knowledge of hygiene and of civics as yet fail adequately to reach either their public or its authorities, is manifest in France. For while the Pasteur Institute of Paris still keeps worthy of its great initiative and history, France, and even Paris itself, still remain to an astonishing degree immune to its ideas—their few experts apart; and these still failing to re-educate their town or city; and least of all the villages, which still outnumber all. The terror of a *courant d'air* still prevails: so what University or other public building, let alone tenement house, or even railway compartment, is yet properly ventilated of its air-sewage? So tuberculosis has victims beyond our industrial world; and the like for other dirt-diseases, enteric, and so on. In short, it is not the low birth-rate (to which all other nations are also coming, indeed often have practically come), but the high death-rate, which is the bane and shame of France as compared with other peoples, albeit none are so advanced as they should be. How explain all this backwardness? Largely, of course, by lack of biological and hygienic education. Again, there were till lately only too many places in Italy,—and doubtless still some—where in common prudence one must close the windows at night, not because "night air" (so long dreaded among ourselves, too) is itself in any way bad air, but "mal-aria", understood only since Ronald Ross's work, never yet adequately popularised—means only the best time for the mosquito, be she fever-laden or no. Hence the urgent need of re-education; and this from the biologic, hygienic, and biotechnic viewpoint—as yet substantially outside both the rival camps of classical or so-called modern education; for be this so far scientific and technical, it remains mathematico-physical and chemical all but exclusively: education is not yet biosocial. Here it is but fair, as well as helpful and hopeful, to point to such small beginnings of living nature-knowledge and application as we have here and there in Britain, and of course in France too, and now more widely in the United States, though even there as yet far from enough.

Large and costly hygienic measures like those taken along the Panama Canal belt by the counsels of Sir Ronald Ross, and carried out with admirable practical energy by General Goethals and his staff, would undeniably outrun the Indian budget; yet not the labour-leisure of the Bengal peasantry, once aroused. Meantime, wonders can be done, even by simple cleansing of tank-edges from the weeds needed by the larvæ, and by the introduction of little fishes to eat them, though far more than all that is now required, and speedily. So here a further practical suggestion, not so costly as it may at first sight seem. Since the "improved" gas-bombs, already so well-advanced in preparation for the next war, are known to be sufficient to devastate the life of cities, not to say regions, good people in Geneva and elsewhere are now agitating for wholesale provision of gas-masks for civilian communities, no less than for their sons at the front. Be that idea effective or no, such a large proposal justifies a somewhat kindred yet easier protective provision for the speedy abatement of malaria. How so? As infectious diseases have nowadays to be notified to the public health authority, so should malaria. The patient need not be taken to hospital; for, though it would need time before all homes and individuals can have mosquito curtains, there is little to prevent putting malaria-patients under them, since this would greatly protect the surrounding mosquitoes from becoming infected, and thus carrying the disease to the next persons they bite. This is, of course, no panacea; but only one of the many measures which will have to be adopted as soon as governments, general and local, British and Indian alike, and their public with them, are awakened beyond the routines of taxing and policing, and to the necessity of saving Bengal, Ceylon, and more, from further depopulation and ruin, and towards return to their old and normal health and wealth.

HUMAN INFLUENCE IN PLANT ECOLOGY.—Since man's advent, he has been wielding influence and gaining power over organic nature, and this increasingly, as in our own times. All this with very mingled results, since so easily for evil, and so difficult for good: witness especially his vast deforestations, as not only for fuel and timber, but as clearings from earliest agriculture onwards, and in our own industrial age. All this we are tardily beginning to see must as far as possible be made good; as not only in our own islands, but along the Mediterranean, and as far as may be into Asia as well; and so, too, for North America, etc.; in fact wellnigh for the wide world's coming statesmanship, with its geotechnic policy, its veritable armies for reafforestation. Thus with all appreciation of the autumn beauty of Scotland, with its purple heather and golden bracken over hills and dales, and with the green mosses of its peaty levels, we yet cannot but also see these as weed-wastes, created largely by past

recklessness; and so we turn towards reclaiming their respective areas, and often towards afforestation anew, the former especially so.

Over increasing areas, even on the Mediterranean, yet more in India, and above all in Australia, we see the spread of the "prickly pear" cactus (Opuntia), as a veritable curse, of which present methods of extirpation are far from easy, or even adequately successful. Yet the study of such unpleasing prickle-patches reveals that they are actively serving nature's end, by renewing soil; and next that as this soil forms, other species begin to appear among them; which indeed sometimes begin to replace them, by spreading over them and robbing them of the full sunshine they require. With further study, and due experiment, the ecologist may thus become of substantial reclamation-service over areas deteriorated and infested.

Again, with the ever-increasing world-demand for paper, we are becoming as it were sub-foresters, for its useful plants. And with the advancing chemistry of cellulose, and its potential transmutations, as to glucose, etc., and with fermentability also, we have before us sources of food and of power, which point to a great future for "weed-farming". Indeed, this at many points seems destined to be at once more easy and more profitable than has been or can be our traditional farming, with its costly wars with weeds!

PLANT-BREEDING.—One of the most substantial examples of the high economic value of careful plant-breeding is afforded by the current advances in the quantity and quality of potato-crops, and the increase of their immunity to diseases. The great famine of Ireland three-quarters of a century ago was but the extreme case of such calamity; and to have since produced, by selection and from new sowings, varieties at least more and more immune to Peronospora, was one of the great achievements of the breeder's art, even before its Mendelian impulse. But there are only too many other diseases; as from leaf-curl and mosaic to scab and other pests upon the tubers. In such cases the mycologist and bacteriologist give valuable aid; and their colleague the entomologist has also had his turn, as notably with the famous Colorado beetle, which his vigilance is now checking from widening havoc. The breeder's art, however, remains the central one. The climate of Scotland, as especially that of West Lothian and Angus, has proved peculiarly favourable for such skilled and selective cultivation; the more since seasons otherwise ungenial may give the best results. For the apparent hardship of having to lift a crop of potatoes which cold and lack of sunshine have kept small-sized and imperfectly matured, often carries with it the compensation that such tubers, planted as "seed", may give more vigorous plants and better yield than do ordinary matured ones; so that the light crop, otherwise only fit

for feeding stock, may bring as much or more for this use, than a bearing one would have done in the food market. Even for food purposes at their highest standard, as for restaurants, clubs, etc., the best Scotch potatoes fetch prices at highest levels; hence an ever-increasing demand for seed-potatoes of these varieties; and not only from English farmers, but now also from many continental countries as well, and even as far as India. This trade is not simply assured because of the long-known advantage of larger and better yields of crops of many kinds when propagated from seeds or tubers brought from a distant locality; nor even because even those far-fetched varieties are for that reason apt to diminish in their returns after a few years of acclimatisation, and so to need renewal; but also because still better varieties are constantly being produced. A notable factor is that a reputation for probity has been established; and this deservedly, from the ever-increasing care of each new variety on cultivation to prevent any contamination by other kinds. The best "seed" farmers not only select their tubers, and scrutinise their manure, lest it bring in small potatoes from other stocks, but even take care to plant their picked stock in land which has not been used for potatoes for as much as six preceding years. Even after all this preliminary care, their best workers are trained to search through the growing field for "rogues", i.e. to recognise young plants of any other variety, and to weed these out to their last tubers with the same care. So after all this, their guarantee can be safely taken: though again the Board of Agriculture is available for its verificatory Report; in which even an impurity of $\frac{1}{2}$ per cent. is sufficient to lower the grade from A to B. Such care is of course expensive: but the prizes, to the skilful breeders especially, are great: for fine new seed-potatoes have sometimes been sold, in their first season, for their weight in sovereigns and more; and this to expert cultivators, who rapidly propagate from them in quantity, for sale to farmers, and this at an attainable price, though still a profitable one.

Similar care, alike of breeding, selection. and culture, is increasingly being taken throughout the agricultural world, and that of horticulture, too: so that good varieties and "pure lines" of these can increasingly be relied on. Hence the old indifference or prejudices of the self-supposed "practical man" are abating, though too much still lingers, as ignorance in the public and their leaders also. It may be remembered that a would-be economist in Congress some years ago proposed to cut down the annual grant for the U.S. Department of Agriculture, and in favour of his would-be practical desideratum, of more battleships: but as reference to statistics over a reasonable period of preceding years showed its services, in crop-improving and crop-saving, to amount to more than \$2,000,000,000, it was permitted to continue its activities, if not even to extend them.

INFLUENCE OF THE SCOTTISH FAUNA

As a particularly interesting case of the inter-relations of animals with human life, we may briefly consider the Scottish fauna. The student will readily extend the survey to other countries, such as North America.

1. In ancient times—long before the Ice Ages and long before Man reached Scotland, the British Area was simply an outlying part of the European Continent, and must have shared its fauna. This was the time of what we call the original European Fauna. But of this there are almost no living remains. None have contributed much to our heritage except the soil-making earthworms. Except for science and imagination, it matters little that the mammoth once lived in Scotland.

2. There set in a succession of Ice Ages, interrupted by milder Inter-Glacial periods, and this was a time of terrible elimination. As vast ice-sheets, sometimes 3,000 feet thick, covered the whole of Scotland and the whole of England except a strip along what is now the south coast, all the old tenants went by the board. Nothing lives or dies to itself, and doubtless there are far-reaching influences of these Ages of Horror—lasting even now. But this is a difficult inquiry.

3. When the tide began at last to turn and the ice-sheets melted, there was the interesting time of the re-peopling of Britain from the Continent, for there were grassy lowlands stretching across parts of the present North Sea. The re-peopling brought back not only many mammals, but humbler creatures and many flowering plants. All the mammals we now have came then, besides others that we have since lost.

4. Towards the disappearance of the great ice-sheets and the appearance of great tracts of country into which colonists crowded from the Continent, there seems to have been a marked depression of the land, so that considerable parts of Britain may have presented the appearance of an archipelago. This or some subsequent movement led to insulation—shutting the door to further colonisation as far as land animals are concerned.

5. Thus our question comes to be: What larger animals were established in Scotland when Neolithic Man settled there some ten thousand years ago. Of Palæolithic man in Scotland there is little secure evidence unless in the Inchnadamph caves, though he lived in Britain further south; the firstcomers that we are quite sure of were Neolithic, "long-headed, square-jawed, short but agile-limbed hunters and fishermen", using well-fashioned stone implements and weapons.

What higher animals greeted Neolithic man when he arrived in

Scotland? All that we have now, except rats and rabbits and domesticated forms. And to these must be added some that we have lost, like reindeer, bear, and wolf. They may be divided into three contingents—those distinctively Arctic, like the reindeer and the lemming; those of the forests, like the Red Deer and the elk; and those of the plains like the hare and the Wild Horse.

In regard to the relations between man and the fauna of Scotland, the classic book, of first-rate importance and workmanship, which would have delighted Buffon himself, is Dr. James Ritchie's *Influence of Man on Animal Life in Scotland* (1920), and to it we are of course vastly indebted. But the particular aspect considered in this section is not so much the influence of man on the animals, as the influence of the animals on man.

6. Let us take, then, some of the most outstanding of these animals that greeted our Neolithic ancestors when they came to Scotland. Let us ask what these animals meant for man, how they entered into his heritage and ours. For some of them that disappeared long since had probably a lasting influence. They formed at any rate part of the sieve in which man was sifted.

I. LARGE ANIMALS OF THE CHASE.—Reindeer, probably of the Woodland or Caribou variety, persisted in the north of Scotland till the twelfth century, and must have been of importance for food and clothing, just as in Lapland and other northern countries to-day. But they were not domesticated. The hunting of the reindeer must have been part of the education of Neolithic and Metal-working man. Here also should be included the Elk, the Giant Fallow Deer (Irish Elk), and the Red Deer.

Appearing first in Inter-glacial deposits, but lasting for many centuries along with man, on probably to the ninth or tenth A.D., was the Wild Ox (*Bos taurus primigenius*), or Urus, once widespread in Europe. Man did not domestic it in Scotland, but it may have crossed with the Celtic Shorthorn (*B. taurus longifrons*) which he brought with him when he came. This Urus was a prize, and an agency in the evolution of the qualities of the hunter. As Cæsar says: Great is their strength and great their speed; they spare not man nor wild beast on whom they may cast their eyes.

The Wild Boar (*Sus scrofa*) came to Britain from the forests of Central Europe, and was very abundant in Early Scotland, and it is of peculiar interest and importance because it was domesticated here. It seems impossible to draw a line between herds of wild boars and herds of half-domesticated swine. Names like Boar's Hill and Swinton, as it were join. The Boar was not only a prize and a sifter; it became stock.

It may seem to some surprising that we are not giving prominence to domesticated animals, for surely they have influenced man and his life more than all the wild animals put together. But the answer

is plain. The Celtic Shorthorn was brought to Scotland; it was not domesticated there, and so with most of the others except the pig.

There is an old-fashioned race of sheep in the uninhabited island of Soay in the St. Kilda group, a race which links with the Wild Mouflon of Corsica and Sardinia, one of the ancestors of domesticated sheep; and there is an old-fashioned Turbary Sheep in the Shetlands, a race which links with the Neolithic "peat sheep" which were shepherded through a great part of Europe by Neolithic man; but there is no reason to believe that sheep-domestication occurred in Scotland. That race-improvement continued is obvious, as to this day.

There were wild horses in Scotland before man came—the Celtic Pony type, *Equus agilis*, common long ago in Western Europe, and traces of these linger in the Hebridean pony and the Shetland pony. A herd lasted on, they say, in the Forest of Birse till 1507; but the main stock of domesticated horses probably came in the train of the Neolithic herdsmen from the Continent, notably, perhaps, from Scandinavia.

II. THE LARGE CARNIVORES.—The early history of the wolf in Scotland is obscure, but there is no doubt as to its former abundance and fierceness. "This regioun, throw the cauld humouris thairof, ingeneris wolffs of feirs and cruel nature". According to Boece, the slayer of ane wolf was to have ane ox for his reward. In 1010 in the forest of the Stocket, near Aberdeen, Malcolm II was saved from a wolf only by the presence of mind of a younger son of Donald of the Isles, who got the lands of Skene in recognition of his timely aid. Compulsory wolf-hunts were common even in the fifteenth century. Spitals, like that of Glenshee, owed their origin largely to the need for protecting travellers from the wolves that became especially bold after nightfall. How many names, like Wolflee, recall the fierce creature—one of man's great sifters and spurs. The shrinkage and the burning of the forests reduced the wolves, but some lingered till the seventeenth century, perhaps even to 1743.

Along with the wolves we may rank the Brown Bear, which lingered in Scotland into the Christian era. We know that Caledonian Bears were transported overseas to Rome to display their fierceness in the amphitheatre, and they probably lingered in the forests long after the Roman legions had gone. The bear formed part of our sifting, and perhaps the lynx helped the early shepherds to foresight.

III. SMALL CARNIVORES.—As to other carnivores, such as fox, badger, otter, polecat, stoat, weasel, marten and wild cat, all with us still, the second last dwindling towards the vanishing point, they have a threefold importance to man. First, though none are dangerous to man himself, some are hostile to his poultry and the like, therefore man must be on the alert against them—up to the limit of upsetting the balance in the opposite direction and allowing the

increase of mice and voles, and other small pests. Second, in early days especially, these smaller carnivores were of considerable importance for their fur. Thirdly, their greatest human importance was probably in keeping alive for a longer time the hunting habit. Some anthropologists, like Prof. Carveth Reed, are making out a good case for the formative importance of the hunting period, which came before the agricultural and pastoral. It seems to have entered very deeply into human nature and left indelible marks. Even from the fox's point of view there is something to be said for the hunt.

IV. MARINE ANIMALS AND FISHERIES.—Along with the terrestrial carnivores we must think of those of the sea—the seals, for these have often been of human importance on our coasts, especially in the West. Seals yield food, oil, and fur, and the seal-hunt educates good qualities, of seamanship and more. In 1830 MacGillivray wrote of Gaskir (or Haskeir), twelve miles from Harris, that "great numbers of seals are killed upon it annually, upwards of a hundred and twenty having been destroyed in one day". This is always man's sad way—the ruthless savage comes alive again and furious greed brings legitimate exploitation to a sorry end. The walrus used often to visit Scottish coasts, but it was persecuted into extreme rarity, indeed practically into disappearance.

In our survey we must not forget the whales, for though the larger and more valuable ones have never been common enough in Scottish waters to lead to systematic local whaling, we must remember the old days of the Peterhead and Dundee fleets. These fostered an adventurous spirit and strenuous vigour, and they had far-reaching consequences—more important than whalebone; as for instance the active aiding both of Arctic and Antarctic exploration. Smaller whales, like the rorqual (Balænoptera) and the porpoise, have often saved the economic situation in the Western Isles, and apart from oil they were often used as food as late as the seventeenth century. The trouble with all whaling, however, has been that man ends it by his greed.

This may be a convenient place for a reference to the familiar fact that one of the most important parts of the Scottish faunistic heritage is the abundance of fishes in the sea. How far-reaching in its social and economic aspects has been the development of sea-fisheries. How important also in fostering a fine type of man, fitted for the strenuous and adventurous calling. "I've brought up three families", a Lewis man said proudly, "on the point of the heuk". Now the good fishing in the North, as compared, for instance, with the Mediterranean, depends on the abundance of the marine Plankton that is characteristic of northern waters.

Let us think for a moment of what we should like to do with a subject like this. Just as it is important and illuminating from the geological side to ask what the Coal Measures have meant for man

in Scotland, or from the botanical side to ask what barley and oats have meant, so, if one had knowledge and insight enough, one should ask what Fisheries have meant; and even more precisely, what particular fishes, like the Salmon, have meant. Each raises questions which it would require years of study to answer. Similarly, of course, one should inquire into the social consequences of the Red-deer, or of the Red-grouse—the last being a species peculiar to Britain.

V. SMALL FOOD ANIMALS.—In early days, before there were great flocks and herds and a perennial killing of sheep and cattle for food, minor sources of supply were of course important. There was trapping of biggish birds like wild geese and ducks, and biggish mammals like hares. The two species of hare may be taken as examples of this group; but it has to be noted that their frequency is quite modern, being incident on the spread of agriculture and the consequent increase of the creatures' food-supply. Dr. Ritchie tells us that in 1707 shooting a hare was punishable under a penalty of 20 pounds Scots; in 1848 anyone could shoot a hare, even without a Game Certificate; in 1893 the Hares Preservation Act granted a close time to the over-persecuted creature.

The reason for not including the rabbit is well known. It was not present in prehistoric Britain; it is not mentioned by Cæsar as a British animal; it was not introduced by the Romans; warrens are not mentioned in the Domesday Book; there is no Celtic name for the animal. In fact the rabbit was unknown in Britain before the Norman Conquest, though it was already common in Scotland by the thirteenth century. In the strict sense the rabbit cannot be called an indigenous member of the British Fauna. Of course along with smallish food-animals we include those caught for other reasons, e.g. the beaver, till the end of the thirteenth century. Yet the rabbit has manifold importance, alike for evil or for good; and as to the beaver, his reintroduction might have more than simply zoological interest. The coming National Parks, at least, might surely find a place for him.

VI. SMALL PESTS AND FRIENDS.—Exercising considerable influence on man's interests are the native rodents like the voles and the mice, whose destructiveness to crops and stores was multiplied when the rats came. For both the Black Rat and the Brown Rat are aliens, the first dating from about the time of the Crusaders and the second from about the middle of the eighteenth century. But along with the small pests we must take the small friends like mole, hedgehog, and shrew.

VII. ESTHETIC TREASURES.—The seventh and last group of animals which we would recognise as forming an important part of our heritage are the things of beauty which are a joy for ever. We have, for instance, about 400 different kinds of birds, many of which have thrilled man deeply. No doubt a few are injurious

to his interests, like the wood-pigeon, which destroys much grain; and the herring-gull, too, is becoming mischievous to farmers. Many are useful, as in destroying insects injurious to the farmer; but let us recognise another aspect, that they minister to our life of observation and thought, of feeling and esthetic emotion. What an impoverishment of the poems of Burns and many another if all the references to delightful living things were removed! Beautiful birds and beasts form a spiritual asset, an irreplaceable part of our heritage, of which we ought to be—far more than we are—the jealous trustees.

Thus, to sum up, from the anthropocentric point of view we may distinguish in the Scottish Fauna:—

(I) the big creatures used as food before there were domesticated animals;
(II) the large carnivores: the primitive sifters;
(III) the small furred creatures;
(IV) marine animals and fishes in particular;
(V) the small food animals, such as the two species of hare;
(VI) the native pests like mice and voles, and the little creatures that are man's helpers, such as moles and hedgehogs;
(VII) the esthetic treasures, birds in particular.

BIOLOGY AND ETHICS

In obeying the command to consider the lily and how it grows, and this to flower, we of course do not credit it with any consciousness, as we understand this. Yet in biology—even apart from that psychology of the sub-conscious which can no longer be excluded from the study of life, even from its simplest forms onwards—we cannot at all understand our lily save as a development, in which root, stem, and leaves, though at first seeming only concerned with individual maintenance, bring forth flowers concerned with race-continuance; and whereby the whole plant, thus fully grown, attains a far further, fuller, and finer development of its own individuality as well. Hence, although the self-maintaining life at first seems to proceed but on the lines of the individualistic economic and utilitarian doctrines which attained such wide acceptance with our industrial age and its competitive and militant outcomes, we cannot but see these as but so many futilitarian misunderstandings of the real process of organic life; and this even in its individual development, as well as its racial evolution. For it is in this due and necessary subordination of each and every individual life to that of its progeny and species, that its essential and characteristic individuality is also attained. And since this method and process of development, less or more fully expressed, is universal throughout

the plant and animal world, we cannot but see that—despite all that can be said of and for "the struggle for existence", even to its aspects of "gladiators' show"—such struggle is still nerved by and towards life-realisation, and with individuality thus so far attained, expressed and enhanced accordingly. Man's psyche, in its exceptional awakening to consciousness and inter-communication, has long been striving to realise this general life-process; and thus in his own different life-stages and civilisation-phases; so with different expressions, different emphasis on its different aspects, from earliest self-maintaining efforts to fuller species-advancing service. Hence throughout the study of past civilisations we find this life-progress, however largely arrested on various levels, and so recognisable, even in active life from its rudest, thought at its crudest, and with these uniting into egoism at its dullest, competition at its severest, and culminating in war towards its harshest. Such limited developments, ferocious in war and base in its intervals of so-called peace, have thus not only been recurrent, but intensifying throughout recorded history, as our passing generation so well knows; and hence the perversions and misrepresentations of man's progress and evolution-process, so characteristic of the competitive types of thought and action, still too predominant in our time. Yet even in these, it is easy to see, as did indeed the very sophists of utilitarianism, that even the most sordid competition, the most ruthless war, are yet moved, and more than sub-consciously, by and to species-maintaining efforts, however narrowed in their range. Returning then to higher expressions of human development, on its maturer and higher levels, we also find more or less of these in all past and present types of humanity, even the lowest and simplest, since anthropologists have come to know and understand them. And here, of course, more fully the historian; and this especially when he starts from (or works back to) that most world-significant of all historic periods, that of about B.C. 700–600, in which a survey of the world from east to west shows us, as, broadly speaking, simultaneous, the teachings of Confucius and Lao-Tze in China, that of Brahmins and of Buddhist and Jain founders in India, of Zoroaster and of the Magi in Persia, and "the Finding of the Law" in Judea. See also Egypt widening its vast culture-influences, and recall the sages and poets in Greece, the founders and law-givers in Rome, and the Druids in Gaul and Britain. Repeatedly since there have been great philosophic, ethical, and religious developments, but never again so many, even to world-wide. Yet the intercommunications of our day are bringing the world together; while the regional spirit and collective individuality of every people, small or great, are also so increasingly re-affirming themselves; yet increasingly with aspirations and endeavours towards concord. So, despite wars and rumours of wars, not to be optimistically disregarded, may not the evolutionists of

humanity again, and before too long, widely play their part?—and this time in increasing measure of unity as regards main principles, and with due respect and appreciation of regional and cultural differences?

HUMAN INDIVIDUALITY, HOW DEVELOPED?—That the babe cries for milk, that growth needs corresponding quantity of food, and that maturity may become more critical and exacting as to its quality, are of course fundamental facts for economics as well as for physiology: yet only as the beginning of these studies. Since these nutritive and self-maintaining needs are of course fundamental to each individual life, and throughout its course, the economist and the politician are thus liable to arrest at this level of knowledge and action: but the physiologist and the physician know better. As clearly in their simple biological way as can priest and poet with their psychological insight, they note how in the passage to puberty and to adolescence new stages of individuality are reached; and once more when pairing-time arrives. This too is followed by further and fuller development with parentage, and this not for the mother alone, but psychically and practically for the father also. As offspring develop, collaboration towards the prolongation of the age of protection and education involves both parents in endeavours which further individualise them both. And when this younger generation comes to have offspring of its own, the grand-parents normally mature yet further, as well as rejuvenesce into a return of their own early parental feelings. Hence not only a widened interest in their various lines of progeny, but normally also a fuller extension of this feeling to childhood and youth in general, which in normal societies has ever been recognised as of patriarchal character. Such sympathetic life-experience and its reflective interpretation, with deepened moral intensity, and intensified volition, tend to individualise the aged pair far beyond their former selves; the male parent specially towards reflection, decision and authority, and the female specially in memory, insight and influence. With such culminant individualities recorded and recalled in serial retrospect by their descendents, we understand more plainly the ancestral reverence so often manifest, from the book of Genesis onwards. We see here the origins of Chinese ancestor-worship, and its analogues in Japan and elsewhere; and which the pride of family among Western peoples has at times approached.

Here we may now conveniently summarise this outline in graphic form, for the graduated rise of individuality (I) to the various levels of our ascending series, from I to I^2, I^3, I^4, etc., and with ♀ and ♂ for the two sexes, and O for their offspring. So from unpaired individuals it reads upwards:

6	*Community Guidance*	I^6	♀♂ [ ] + [ ] + [ ] ♀♂
5	*Grandparents and families*	I^5	♀♂ [(♀ O ♂♂) (♀ O ♂) (♀♂)]
4	*Family enlarged*	I^4	(♀ OOO♂)
3	*Family*	I^3	(♀ O ♂)
2	*Pair*	I^2	(♀♂)
1	*Separate*	I	♀ or ♂

This beginning of a notation may next be carried on beyond family levels into wider community guidances, as described by anthropologists or recorded by historians—so from simplest village council and court, to Roman Senate or yet wider groupings at Geneva to-day: but into these we need not enter here.

It will be evident that this beginning of a notation may be further developed, as to outline other and further developments, of family to society, as described by anthropologists; but into these we need not enter either. That this sexual and family development of individuality is neither so fully or finely illustrated in our present civilisation as it has been in others is a matter for the sociologist to inquire into: our point here is but to note (and notate) the normal bio-social and bio-psychic processes and factors. These explain those elemental superiorities of individuality in maturity and age (despite decreasing numbers and even declining physical strength), which are more or less manifest throughout all forms and phases of human societies. It also becomes evident that this first outline diagram may be adapted, as by the eugenist, to each family's development; and it may also be carried further upwards into all forms of social development, with associated political or other ascendency; and of course in peace and war.

Yet more important, however, is to note that in so far as this ascending ladder of individuality is not climbed, there are corresponding opportunities—manifest throughout life and history and largely availed of—in the opposite direction, and with corresponding ob-individuations. Thus leaving the reader to draft this outline—which he can vary and elaborate to suit the particular problems it may suggest—we may note the easy descent, from the initial normal level of nutritive self-maintenance to that of excess or misuse, as from childish greed to our frequent adult gluttony and intemperance, our resultant sloth, and our drug-habits, whether for promotion of this, or arousal from it. With the onset of sex, especially in those missing the first step of the ascending ladder, it is only too easy to find the corresponding step downwards; and so to range this through any to every form of pseudo-celibate licence; and also to reach the next lower one, of adultery and its family disintegration. Again, when the further and fuller individuality of responsibility, widened beyond immediate family, is not ascended to, the corresponding

irresponsibility, of economic and social "individualism" in its yet worse sense, can be readily acquired. And so on downwards, in symmetric parallelism, to fuller and fuller ob-individualities of social treason, of which the degenerate Cæsars are far from being the latest representatives. So while this graph is plainly adaptable to scientific developments in both directions, it also needs but a little imagination to see in it, at its ascending best, the ladder of Jacob's dream, with its psychologic and other expressions at various further levels. So next we may draw out the one below; and not only to the elaborations of Freudian and other pathological studies, but to criminological ones. We may even compare these levels with the circles of the Dantean Inferno; for though that masterpiece, of social survey and of individuality-interpretation, is still far from being adequately overtaken by science, surely here we are on a way towards appreciating its main outline.

Psycho-Biological Concepts and Mytho-Poesy.—In kindred ways to the preceding, as we set down other outline-presentments of life's aspects as they appear, of life's processes as they develop, we find them also closely recalling concepts transmitted from long past phases and types of civilisation, and their distinctive cultures. Their classic literatures are appreciated accordingly by scholars and poets, by philosophic or religious minds, but hitherto, so far are we aware, not recognised as coming into the fields of evolutionary biology and psychology at all, or still less as again evolving out of these. Yet just as the above graphic outline was simply devised to trace the steps of Individuality-Development, as associated with sex and family; yet, after such uses, it is seen also to recall mytho-poetic traditions; as we often see in other cases. Thus the discussion and notation of the Phases of Life, as manifested in the seasonal growth of plants, in the development of animal life, and next in the life-story of our own species—after years of use in these simple naturalistic ways—is suddenly seen to recall the Olympian Gods; and with freshening additions to the traditional interpretations, which scholars have so long been discussing in their own different traditional ways. Again, take our simple concept of Life (O, F, E) in terms of organism in interaction with its environment, and of human life in similar terms, as of interaction of people and place, with correspondingly simple psychology also. As its graphic outline develops, this soon leads us onwards to a simpler and clearer present-ment than usual of the deeper fields of psychology—religious, philosophic, poetic, etc., which thus find simple and suggestive evolutionary explanation. But later appears the quite unexpected result, that these modes of active life, at its highest, answer exactly to those so long ago expressed in terms of the Nine Muses; while, on the other hand, those of misadjustment fall into the old categories

of the Three Furies! Again, our simple graphic Psychological Outline triangle, suggesting senses serving intelligence, emotions taking expression, and will guiding action—and devised solely for that purpose—is next seen strikingly to recall the ancient conception of humanity in divine image. Again, in the dawning cosmos, before the coming of life, for which the recent advances of mathematico-physical sciences are reaching such new conceptions of Space, Time, Matter and Energy, what are these but fresh presentments of the primeval Nature-powers of ancient thought—Ouranos, Chronos, and Ge?

In short, then, these past conceptions of ancient culture, formed ages ago in their own ways, are found to reappear on such logically developed life-schemata, arising in terms of biological and related psychological thought alone. This coincidence of conceptions old and new, from different cultures and times altogether, is surely worth noting, and even reflecting on. For one thing, here are mutual confirmations, wholly unexpected and unsought, either by scholars of the past or by evolutionists of the present; and thus suggestive to both; first in their own ways, next towards better understanding; so why not even encouraging towards collaborations? To us evolutionists, rationalistic moderns if ever there were any, it is of no small interest, and broadening result, thus to realise how fully and finely some of the conceptions arising from our own studies have been anticipated, even surpassed, in far-away traditions, from which in some respects we have formerly struggled to emancipate ourselves. And may not scholars also come to view our evolutionary endeavours no longer as harsh iconoclasms, but as recovering, for our times, great conceptions of the past, to them beautiful, venerable, and even sacred. In short, are we not here seeing how these old poetic myths were true to life? And next how life, in evolution, may renew the like ideals? If so, we are thus alike being led to a more synthetic view of history and progress; as yielding, in various times, and under very various conditions, large conceptions of life and its possibilities, which, however differently reached and expressed, are yet fundamentally akin. If so, we may now more fully and vitally correlate them. And if these past and present studies, of the humanities and of the sciences, can be thus increasingly reconciled and harmonised, may we not look forward to a co-operation of scholars and scientists, and with artists too, recalling that of the Renaissance?—since bringing a more unified and vitalised education, and this in its best and fullest senses, to bear on our confused and perplexed world? In this way, as in others, despite difficulties and dangers, are we not approaching an understanding more sympathetic, and thence action more effectively social—in short towards a fresh step in evolution, a literal period of Revivance?

THE RELATIONS OF BIOLOGY TO SOCIAL SCIENCE.—In a previous section it was shown in detail that the eight-fold grouping of subsciences which make up biology holds good for the other main sciences too; and this not only through and from our social development, but also on logico-mathematical and physical grounds; since inevitably delimited in terms of space-forms viewed analytically or synthetically, of energy-states, kinetic or static, and of time-phases, past, present and possible. Individual and group studies, in their active and passive aspects, and their evolutionary process, in biology, and indeed in each and every main order of phenomenal interest open to investigation, are thus clearly recognised and arranged for; and these in more orderly treatment than is yet customary, and with increasingly clear co-ordination of their special fields and inquiries.

That this eight-fold method of study applies to the study of man, viewed by the biologist as the species now, on the whole, nearest world-dominance, is obvious, at any rate with a little reflection; the more since it was with his physiology and anatomy (normal and pathological) that biology began to come into being. So too his ethnography and his social groupings have been suggestive to early classifications, as also greatly by the need of getting medicinal herbs into order. Embryology was stimulated by the human curiosity and medical inquiry into the mysteries of gestation and birth, and of course around the relations of the sexes also. Human economic experience, from gathering, fishing and hunting onwards to pasturing and agriculture first gave us that interest and knowledge of the ways of living beings, which next—of course with the observations of free curiosity as well—became collected into the old Natural History, up to and from Buffon; and which is now pressing, through and since Darwin above all, into that more comprehensive Ecology, of which in this volume so many aspects are indicated and illustrations are given. In all these studies, moreover, the human element is not centred on the human individual, but is obviously a general one, ranging to human kind; in which our concept of the species was not the initial one, but that of family or horde, of tribe or other form of community. Man's first conceptions of these in his own kind may well have been helped into existence also by the animal herds, fish-shoals, bird-flights, and wild bee-hives of his earliest economic endeavours and experiences. Here, then, in such groupings, animal as well as human, with their dawning "consciousness of kind", we have a meeting-point for early thought; and this has continued helpful in modern times on one hand for our studies, by turns ecological and formal, of animal societies, and next of plant associations, on the biological side; and on the other hand for the inquiries into human community, throughout all its forms and grades, all its ways and doings, which we are learning to recognise as the cognate

science of sociology. How this has differentiated from biology pure and simple is of course an inquiry only to be outlined within our limits here. Yet its separation from biology, its differentiating and distinctive character as a further and yet more complex science, has to be broadly defined: alike for clearness' sake and as defence against those undue claims, not only of adequate understanding, but even of mastery, and legislative if not even despotic rule, to which even biologists have been of late years inclined. And these not merely ultra-Darwinian, even to militancy, in war-time; but sometimes the most socially-minded and well-meaning of them—even some of our contemporary eugenists for example.

What, then, is this main differential character which separates and distinguishes sociology from biology?—and so defends it from excessive pretensions of biologists, though admitting their just claims, and accepting their contributions to the full? This distinctiveness of sociology for humanity lies in its essential concern with the *Social Heritage* of civilisation; something apart from and beyond that *Organic Heredity* of man which is in the province of the biologist of man as animal, i.e. as of given species and variety, race and sub-variety, parentage and family connections, in short of Breed. Socially important though the unravelling of all this field of heredity and organic relationship has been, is, and must increasingly become, even the study of heredity towards the practical realisation of good and better breeding in humanity—needed and hopeful though this be—has been, is, and remains essentially, a development of biology in science; and necessarily fundamentally akin to agricultural stock-breeding applied in practice. But the eugenist tends to claim all this not only as sociological, but even sometimes as the very crux of all social questions. That the sociologist welcomes this contribution is evident; thus Galton's classic papers on Eugenics are justly reckoned by the Sociological Society as probably the most significant and certainly the most influential of their whole publications; and they are gratified, as well as sometimes a little regretful, that the Eugenic Society soon thereafter hived off from them as a separate swarm. Yet what was the reason for this separation of these active students of human heredity and breed? Primarily their recognition of the definiteness and urgency and importance of their problem, and the vastness of its field; with need of concentration of experts accordingly, and for discussions and publications alike. Between the general biologists on one hand and the general sociologists on the other, they needed a clear field, that of the full extension of biology as fundamentally underlying the study of social life. Recall other fundamentals of sociology, and and of other sciences too. The arithmetical, graphic and further mathematical skill, ably applied to the study of social phenomena, as by Quetelet and his successors, has opened for us the vast field of statistics, as from

finance to demography, and with censuses, statistical societies, journals, treatises, etc.: and in more recent times, the like mathematical and statistical minds have ranged into (say rather *under*) the strictly biological field, and given us their new specialism accordingly—that of Biometrics, again with its earnest and able workers, groupings, and publications accordingly. Nor has such progress confined itself to each immediate field thus opened; for since the experimental breeding initiative of Abbot Mendel in Darwin's time was re-discovered and developed in our own, we have the new and valuable specialism known as Mendelism, radiant with interpretations of the appearance and disappearance of varieties, if not yet even of species; and its new light upon heredity gives impulse to animal and plant-breeding. It has, indeed, aroused these great old arts from their empirical traditions and methods to rational and successful applications of science, which are already productive as regards stock, crops and gardens, and even interpretative and promising as regards eugenics. Biometrician and student of heredity, breeder and eugenist, are thus increasingly coming together, and throwing fresh light into social science.

Can we wonder then that such specific advances of biology, and these in association with its preliminary sciences too, have seemed to many of their workers, and their readers, as the very making of the social science; and this the more since it must be frankly confessed that the would-be sociologists proper have as yet seldom such clear scientific advances to boast of, much less such concrete results in practice to show.

Yet to this question there are two answers. First is that of noting and clearly locating each and all the special fields above recognised. Here appears the illumining usefulness of our preceding charting of the sciences, of which the diagrammatic presentment provides space for each and all of these new fields. So it may be summarised in outline, and thus as not entering the special field of sociology, though basal to it—as its "legitimate materialisms". Mathematics (1) has long been potently aiding the physical sciences, without superseding them; and next throwing light on biology with biometrics, and yet more on sociology by statistics. (2) Mechanical, physical, and chemical sciences are all needed preliminaries to biology and for physiology especially, and also offer increasing contributions to social science. And so also (3) Biology—in all its sub-sciences, especially the kinetic ones, physiological and ecological, ontogenetic and phylogenetic—has long been making great contributions to the social sciences, and indeed teems with suggestions for more, so that a section is needed to indicate some of these biological fundamentals to the social science, albeit in mere outline.

It is easy to see on this diagrammatic stairway of knowledge the

succession of these four distinctive sciences, mathematical, physical, biological, and social, and to realise their own ascending complexity, and their respective dependence upon their predecessors: so that each (after the first) can only be substantially based and supported by the extension of the preceding ones, so far as they can go towards elucidating its problems and expressing their contributions in their own distinctive ways.

The mathematician and the physicist have longest been working

			SOCIOLOGY (*proper*)
		BIOLOGY (*proper*)	Social Biology, e.g. *Eugenics*, *Hygiene*, etc.
	PHYSICAL SCIENCES (*proper*)	Biophysics and Biochemistry (Branch of *Experimental Physiology*)	Social Physics e.g. *Coal, Oil, Machinery, etc.*
MATHEMATICS (*pure*)	Mathematics of Physics	Biol.-Mathematics (*Biometrics*)	Social Maths. (*Statistics*)

together, and thus peculiarly understand each other's bounds. But the trouble begins when the statistician of biological phenomena, and more of social ones, thinks as he has long done, indeed too often still does, that these sciences are thus to be practically perfected, and so only await his strictness in the matters he has still to count and graph. Thus have arisen exaggerations of the claims and conclusions of biometrics. But far more serious and enduring have been those of limiting the conceptions of economics—assuredly a social science if ever there is to be one, and also dependent on physical

and on biological conditions—by pecuniary considerations as not only fundamental but supreme, and so founding upon market experience the so-called "immutable laws of political economy", as of absolute world-authority accordingly, instead of understanding them as but the numerical record of the resultants of all succeeding phenomenal changes, both physically and biologically social, as well as social proper. Ruskin failed to convince the economist of the truth of his criticism of their limiting the conception of value to money prices alone—viz. that a loaf of bread of given quality and weight has a fixed value, quite independent of its changing money price in the market, that of maintaining an average worker for so many hours. He was talking sound physics and physiology in one, in fact anticipating the physico-physiological conception of "calories", though that word was not yet coined. Stanley Jevons however, as a pioneering modernist economist, and dealing with coal—a more interesting subject to many than bread, yet undeniably connected with it—awoke his fellows to some understanding of such physical economics. Yet ordinary teaching and text-books still show too little influence from this; so fortunately one of our formeost physicists, Prof. Soddy, has lately set about convincing them anew. Yet even if he triumph, and schools of economics progress into elementary physics as he asks, the biologist still needs to give his social contribution. The physician, as sanitarian and hygienist, has been still longer in the field, and with increasing practical results, to show Ruskin's seeming "sentimental" dictum—"there is no wealth but life". The eugenist biologist now fully maintains and extends this, as fundamental to social life and science. He proves that good breeding is fundamental to the very maintenance of civilisation; yet sometimes forgets that the supreme aims of civilisation are needed to establish and maintain it aright.

The correlation of these four main sciences, and of their six respectively fundamental sub-sciences is thus broadly clear: the diagram may suggest further developments; of which some are in active progress, and others still needed.

ESSENTIALS OF SOCIOLOGY.—The essentials of sociology, however, need clear outline statement, though but briefly here. Essential then, and characteristic of the social science proper, is the study of human and social groupings, in all their forms, aspects, and doings throughout time and space; and thus of archæology and history, of ethnography and ecology (economics at its fullest and widest), and thence towards the better understanding of the course and character of social evolution. Here, however, the biologist may say—indeed, often has said—Well and good, if this be all, it is but an extension of my province, for man is undeniably in it. For if wonderfully social animals like bees and ants, like beavers and more, are not

disputed to me by this would-be separate sociology, what claim has sociology to separate man for its own province, merely because his social evolution has gone further, and is now more complex?

Yet the reply is easy, and unanswered by the biologist in these hundred years since the first clear outline of sociology. Its new and distinctive factor, a fresh "emergence", essentially outside and distinct from organic heredity is, as already emphasised, that of Social *Heritage*, and this both material and immaterial. Take the former first; as expressed in the region cultivated by man, and the home, village, town and city as built; in short, "the earth as modified by human action". The biologist may here say that is only like greater beaver dams, or larger anthills! Yes, so far; but if King Solomon were to return, he might quite well again "go to the ant", and find that unchanged. But not so with Jerusalem; in which he would find nothing he could recognise, since destroyed and rebuilt oftenest in history, some seventeen times or more since his day, and now in way of rebuilding anew. But ants would rebuild yet oftener if need be! Yes, but in the same way as before; whereas each of these many cities has been something of a "New Jerusalem" in its own distinctive way, and thus very different from all its predecessors and successors. Here appears at length the essential quest of sociology, which needs fuller statement. How indeed? No doubt with ant-like battles to destruction, and with reconstruction by the victors; such is still the lamentable way of man: yet there is plainly more in this history than that, as no biologist will deny. See the Old Testament and the New—separately, and yet in many ways also brought inseparably together—and vast histories besides, which we are still only beginning to unravel, from Egyptian and Phœnician to Babylonian and Assyrian, Hittite and more, before the days of Greeks and Romans. Then again Christians and Moslems, and on to their Crescentades and Crusades, and these in alternation and rival influences to this day; and all with intricacies of relations and antagonisms beyond all others known to history, though every other human grouping has its intricacies too. How so intricate? Because in this location, and in its changing populations, always materially inconsiderable as the great world goes, there has been a succession not only of conflicts but of civilisation movements, each creating more or less of heritage of its own, and some of these again, and incomparably, raised to spiritual powers. For these have emotionalised peoples, through great faiths here centred. Hence to this day, despite extremest vicissitudes unended, this city stands out as the sacred metropolis of Israel and of Christianity alike, and for Islam also as only second to Mecca, which indeed it all but replaced; so a pilgrimage-centre for each and all three. Here then we have got far beyond the scope of biology, and even of all the

simpler psychology that can go with it; and into perhaps the most complex field of sociology; and its deeper psychology as well. But concepts and terms like these of spiritual powers and faiths, of sacred city and of pilgrimage, are obviously all outside and beyond the range of biology at its widest: since each and all are terms of social heritage, beyond organic heredity, and thus above it in significance and influence too. Everything biological, and bio-psychological, in humanity is of course here open to observation as well: and studious pilgrims, with their scientific outlooks and their practical endeavours are needed, indeed welcomed and even employed. But the Church of the Sepulchre, the Dome of the Rock, the Wall of Wailing, are each in their own way, and yet more all taken together, main sociological foci of Jerusalem; and thus beyond biological interpretations merely, well-nigh as much as merely physical ones: indeed, the physicist and mathematician could come as near, in appreciating these domes, in their own relatively simple ways. The man of science, at his present strictest, may see these only as so many curious survivals, each of a theological past for him faded and falling away, and so think such heritages in way of dissolution into the everyday modern world, which is so plainly in evidence around them. Yet he needs only a little more observation to find these heritages renewing, and in modern form, instead of disappearing. For instance, there is the Hebrew University, one with ambitions beyond others, now rising upon the Mount of Scopas, a site chosen not merely for the supreme outlook its name implies, but as that of Titus for that victorious siege and apparently final destruction of the City, which is still proudly commemorated upon his triumphal arch at Rome. And when the biologist inquires further he will find that this University—at once characteristically starting with modern bio-chemistry and bacteriology as well as with classical Hebraic and cognate studies—is not the only one: since Christian and Moslem are already planning how to rival this; in fact beginning, so that that vastest of the world's quadrangles, that of the ancient Temple, has again its student community; and great sites are acquired for the Christian Colleges of well nigh as many denominations as these have convents and churches of old; and even for new ones as well. That these theological traditions are all evolving, and to embrace and to advance the scientific, as well as to maintain and to develop their historic literary and linguistic heritages and more, is thus the incipient social creation of New Jerusalem, the eighteenth or thereby; for since the old metropolis of religions is giving birth to that of education, only primarily for Israel, but also for the world's science and learning, the other faiths, as just said, have had no choice but to become ambitious too. Yet the "City of Peace" is not to be despaired of coming to deserve its name: thus it is a hopeful sign that the

archæologists, of all these faiths or none, already meet, and even publish their results together.

Enough then of this long illustration of the distinctiveness of sociology; and from earliest to latest and most complex—say Les Eyzies and Jerusalem—for types of the study of the changeful social groupings of man, and these not only material, and thus partly physical and biological, but with their spiritual factors, emotional, intellectual, and imaginative, their heritages of religions, philosophies, histories, languages, and literatures, sciences and arts; and all these determining the interaction and flux of contemporary social evolution. And thus—however fundamentally based and modified from without—essentially from within. For this vast heritage is no mere memory: but of the very essence of the social soul; and thus reawakening it to higher developments; for all the Muses are here latent, and some already manifest; albeit the Furies too.

No subject can be more attractive to the geographically and biologically minded sociologist than that of how, as environment conditions life, so the place makes the people; as Holland has so truly done for the Dutch, Switzerland for the Swiss, and so on. This regional and "economic determination of history" is perhaps the best of all examples of the qualities of a half-truth, yet also of its limitations, that the modern world can show; witness its vast and ever-increasing acceptance. Yet though this doctrine can be fruitfully applied in Palestine as elsewhere, the other half of the truth is also here plain, that of how the people make their place, and are ever re-shaping their environment; witness how the Dutch have made Holland, indeed are at it again more than ever; and the Swiss are mastering their very torrents. Men are ever making themselves anew with their environment anew; and so on throughout history, back and forward.

In all this a further concept is needed for the understanding of the Social Heritage: it is never all pure and healthy; we have also to recognise in it and investigate its accompanying burden of evils; far worse than the taint in an organic heredity. This is indeed the hardest of sociological riddles, since nothing less than the great "problem of evil", so long insoluble for theologians and philosophers, separately or together; yet now beginning to yield to the scientific observation and analysis of life, organic and social together. The biologist as physician, and of body and mind together, has been leading the way; and now sociology and biology are learning from each other; and even the political and the economic world begin to learn; though still too little, and that slowly, in the great school of experience, albeit with fees so high.

LESSONS FROM NATURE

Competitive or Co-operative?—There is keen competition in the Animal Kingdom, and there is also intimate co-operation, which is most in the line of progressive evolution? Among some animals the rule of life is "Each for himself"; among others there is extra-ordinary self-subordination, sometimes an almost fanatical service of the community. Which way of living has been most rewarded and which holds out most promise to man? Should he take the individualistic badger or the socialistic bee for his totem?

The struggle for existence is an often misunderstood technical phrase for the manifold clash between living creatures and their environing difficulties and limitations. It may be for food or for foothold, for self-expression or for luxuries. It may be between fellows of the same species, seedling against seedling, locust against locust; or it may be between foes entirely different in nature, such as carnivores and herbivores, birds of prey and mice; or it may be between the living creature and the changeful, callous, physical environment, such as the cold and the drought. Sometimes it is not the individual that struggles, but the community of which it forms a part, as is clearly seen in the raids of the ants.

Darwin was inclined to think that competition was most severe between individuals and varieties of the same species, but he did not give many instances. Apart from reference to the overcrowded seed-plot and the like, he spoke chiefly of the competition between different *species* of rats, cockroaches, bees, charlock, swallows, and thrushes; and even in regard to these he spoke not very convincedly nor convincingly.

Of great importance is it to appreciate Darwin's broad view of the "Struggle for Existence", as in the sentence: "I use this term in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny." This sentence is not itself very luminous, but it is evident from the context that Darwin used the "Struggle for Existence" as a formula including all the reactions and endeavours that living creatures make against environing difficulties and limitations. And now we see the competitive and the co-operative modes of life in their proper biological setting. For they are the two chief ways of reacting in the struggle. One way out is to intensify individual effort, to tighten the belt, to set the teeth, to hustle and jostle, to strain and strive. This is the way of the eagle and the lion. The other kind of reaction is to join hands, to link lives, to practise mutual aid, to subordinate self, to increase parental care and kin-sympathy. It is the way of the rook and the beaver. Thus we see that the two modes of life that we wish

to contrast—competitive and co-operative—are not antithetic alternatives. Both are successful, both have their rewards, and both have their dangers.

It must not be thought that the contrast between the solitary and the social, the competitive and the co-operative, is the same as that between egoistic and altruistic types, between the selfish and the other-regarding. This is a common fallacy. The individualistic otter is just as careful a mother as the co-operative beaver. The golden eagles in their lonely retreat are as devoted parents as the gregarious rooks. The solitary bees provide for their progeny as effectively as do those that live in colonies and hives. The contrast between the competitive and the co-operative is primarily social, not ethical.

What is the contrast? The co-operative régime, which we may also call gregarious, communal, social, and so forth, always implies some measure of self-subordination on the part of the co-operators and some alleviation of the individual's struggle for existence, for society is always a shield. The danger is a loss of individual all-roundness and independence, and a sheltering of weak types that would be eliminated in individualistic conditions. Moreover, as in ant-hill and bee-hive, the subordination of the individual may become almost pathological. The self-sufficient, actively individualistic, each for-himself way of living has the advantage of fostering sturdy vigour and all-roundness of development. But it has the disadvantages that it presents fewer opportunities for the cultivation of kin-sympathy, that it limits the mastery of the environment, and that it may involve an intensification of the struggle for existence to the unendurable uttermost—which spells extinction.

The open secret that Man may read in Animate Nature is that there is much to be said for both the competitive and the co-operative ways of living. Man, though one species, must try both. Towards given ends, at particular times, in certain circumstances, man should learn from the eagle; towards other ends, at other times, and in other circumstances, he should learn from the rook. Both ways are best, whereas no good word can be said for parasitism.

But when the one régime should be followed and when the other is a difficult question, and from Natural History we get but a few hints. Certain modes of life, such as fishing and hunting, favour the "each for himself" policy; certain inhospitable and difficult environments operate against the possibility of a communal régime; certain constitutional and temperamental peculiarities give the animal a bias against or in favour of co-operative self-subordination. Perhaps there is some deep psychical difference between a crow and a rook: the one solitary, the other social; both highly intelligent.

A common fallacy to be guarded against is crediting the particular way of living with engendering all the virtues of those that follow it.

The solitary or individualistic mode of life is illustrated in Britain by wild cat, fox, otter, badger, pine marten, stoat, weasel, hedgehog, mole, shrew, hare, squirrel, and dormouse—a very attractive set of animals, much more attractive than the gregarious types, rabbits, rats, mice, voles, and bats, with the single exception of the deer. But we have to correct this in other countries, remembering the cleverness and loquacity of monkeys, the wisdom of the elephants, the intelligence and adventurousness of wild horses, the defence of the young among gregarious ruminants, the kin-sympathy of the prairie-dogs, and so on. We must not pick and choose when we seek corroboration from the animal world.

Similarly when we admire the effectiveness, the intelligence, the kin-sympathy of elephants, wild horses, beavers, wolves, parrots, cranes, and so on, we must not give all the credit to the mode of life. For in the first place, there is probably some prerequisite to close co-operation, some fineness of material, necessary to start with, as in monkey and elephant, horse and beaver, crane and parrot; and in the second place, there is often a considerable degree of commonplace gregariousness without any marked enhancement of the animal's qualities, as may be illustrated by rabbits, rats, and sparrows. Often, indeed, the co-operative animal has a suggestion of inferiority, simply because the sociality is a shield to types which are not individually very strong, such as mice and slave-keeping ants.

When we consider the co-operative or societary mode of life in its many grades, we cannot but admire the way in which it secures stability in the struggle for existence, the increased economy and efficiency, the possibility of permanent products and tradition, the kin-sympathy and socialised self-subordination, the shield thrown over individual variations and tentatives. It is plain that human progress must largely lie along the co-operative line of evolution.

Yet on the "each for himself" mode of life there evolve notable good qualities: sturdy independence, resolute all-roundness, originality, and a certain fullness of life—until the struggle becomes too intense. Thus it becomes one of the deepest problems of the statesman to guide the communal co-operative evolution so that it does not involve jettisoning the rewards of competitive individualism. That neither man nor bee has solved this problem is painfully evident.

Here indeed we may learn afresh from the flowers, with their range from the solitary extremes of individualism, as in the anemone or the tulip, to the crowded bouquets of the Composites; and even to far extremer repression of the individual flowers, as within the common fig. Flora in her world-garden has thus encouraged all types, individualistic and socialistic, and each at all levels of perfection and beauty of their kind.

BIOLOGY AND WAR.—When a mason builds a wall he continually tests his work with a plumb-line, a level, and a square. He applies three different tests to make sure that he is building well—that is, right in all three dimensions. Similarly in more complex social affairs, where the issue is not clear, it is useful to apply several tests. When they confirm one another, they strengthen our resolution; when they are discrepant, they show us that there is need for further inquiry.

Three such tests, for our life and its doings, are to be found in the ideas of the Conservation of Energy, the Conservation of Life, and the Conservation of Moral Values—physical, biological, and ethical respectively. The first test condemns an undertaking that is wasteful, or that attempts to get more work done than the available energy allows; and the useful criticism that a business man expresses when he calls a scheme unsound is often based on his discovery that physical principles are being ignored. The biological test asks whether the activities in question are consistent with the health of the individual and with the welfare of the race. The third test asks if the line of action makes for the conservation of what we hold to be most precious and most beneficent in our social heritage—the traditions of civilised behaviour, the standard of conduct, and the ideal of good will among men.

WAR BROUGHT TO THE TEST.—In the history of nations it has at times appeared that war was inevitable except at a sacrifice of honour, justice, and liberty. Yet this does not affect the fact that to have tens of thousands of wholesome men in the prime of life mowed down with machine-guns is an extreme of wastage without parallel in history, even in famine or plague. By the first two tests, the physical and the organic, war is condemned.

When we turn to the social or ethical test, we find the issues far more intricate. It has to be remembered (1) that besides what may be inevitable defence, even by the first two tests as well as the third, there may be nobility in the determination to go to war if there is no alternative course consistent with honour, justice, and freedom; (2) that the waging of the war may afford opportunities for courage, endurance, magnanimity, and other virtues; and (3) that a war which can be carried through with a good conscience may leave a nation spiritually enriched. As William James said in his famous essay on *The Moral Equivalent of War*: "Those ancestors, those efforts, those memories and legends; are the most ideal part of what we now own together, a sacred spiritual possession worth more than all the blood poured out." That is the one side of it. On the other side, war is so awful that, as Prof. James went on to say: "Only when forced upon one, only when an enemy's injustice leaves us no alternative, is a war now thought permissible." The fact is that while the willingness to face war in a good cause is noble, and while waging war may engender valour and arouse or freshen idealism, the actual

fact of war is a detestable anachronism, and one full of deadly peril to the character of combatants and non-combatants alike. It seems to come upon the nations because the past is still too strong for them, as a surge of reversion which sweeps them off their feet. Yet also because no better solution has been found in time; and also because the better ideals of Peace have not yet been adequately thought out and set before mankind, save in too simply general and idealistic ways, not yet developed into Policy.

But our special problem here is to apply the second—the biological—test. Leaving, without forgetting, the social heritage, we have to ask how war affects the natural inheritance of a race, and whether there is in Organic Nature any object lesson which may make clearer to us the significance of human warfare.

EFFECT OF WAR ON THE RACE.—Various positions are held in regard to the effect of war on the heritable qualities of a race. (1) There is the view of the extreme militarists that war is indispensable. The nations have to be bled periodically, else they will become soft and adipose. According to Bernhardi: "War is a fundamental law of evolution. War is a biological necessity of the first importance, a regulative element in the life of mankind. It cannot be dispensed with, since without it an unhealthy development will follow, which excludes every advancement of the race and therefore all real civilisation." (2) There is the view that in ancient times war was (sometimes, if not always) an eliminating process that made for progress, strengthening a tribe by the continual sifting out of those less fit, for times when fighting was the order of the day; and strengthening the race by the occasional "wiping out" of a weaker clan by a stronger; but that this discriminate elimination, even if really useful to the race, has entirely ceased with the change of conditions in modern warfare. (3) Hence the position that war is radically dysgenic; that is to say, that it persistently sifts in the wrong direction, impoverishing the race by the loss of a disproportionate number of the more chivalrous, courageous, and patriotic. The best statement of this position is to be found in Chancellor Starr Jordan's impressive *Human Harvest*. We should also recall Darwin's sentence in the fifth chapter of *The Descent of Man*: "The bravest men, who were always willing to come to the front in war, and who freely risked their lives for others, would on an average perish in larger numbers than other men." (4) Some biometricians, however, still hold the severely scientific position that the influence of war on a nation, biologically regarded, has not yet been investigated by competent statistical methods, and that no certain conclusion can be drawn.

Against the view that war is indispensable if the virile virtues are to be kept alive, it must be firmly maintained that in the tasks of

peace there is ample opportunity for valour and heroism, and that the annals of exploration, investigation, medical practice, and the like, are rich in illustrations of the highest courage. To admit, as we must, that there are worse things than war—slavery, softness, dishonour, and moral unsoundness generally—is not to admit that war has been the saving discipline that has kept nobility alive. To admit that a nation may be forced to a crisis where a refusal to go to war would mean disgrace is not to admit that the battlefield must for ever remain man's final court of appeal.

It is reasonable to draw a distinction between ancient and modern warfare. For in a battle in ancient days there may well have been a useful sifting out, on both sides, of the clumsy, the cowardly, and the cumbersome; and a raid may have sometimes resulted in the practical elimination of the weaker of two clans. But in modern warfare one nation does not exterminate another, and the battle is not always to the strong. Even if it can be proved that military efficiency does on the whole tend to secure victory, it is by no means to be taken for granted that it is based on qualities which make for soundness and progressiveness in a race. In any case, we must not argue from ancient to modern warfare without taking account of the changed conditions. Another complication is that a nationality in modern times is often very far from being a biological race.

The severely scientific position that we have not sufficient data on which to base a secure judgment, may be met by indicating three conclusions which have a high degree of probability, although statistical proof is not forthcoming. (1) When a nation with voluntary military service is involved in war the more virile and chivalrous obey the call of their country in larger numbers, and their ranks are disproportionately thinned. Those who cannot fight are left, and those who will not fight are left; and "from the man who is left"—in this case the less desirable—"flows the current of human history", as Starr Jordan puts it. A rapidly decreasing proportion of brave and desirable men must remain at home to keep things going, and the elimination does not very directly affect the women—two facts which go to counteract the impoverishment of the race; but it seems undeniable that a voluntary army raised in a crisis includes a disproportionately large number of those whom the nation can least afford to lose. If the number of combatants were small compared with that of non-combatants, the casualties might not be of sufficient magnitude to affect the welfare of the race; but if Britain, for instance, has to raise an army of three millions and a quarter—that is about half of the male population between 18 and 45—it does not mean every second man by lot, but a larger proportion of the more patriotic and courageous. In this way it seems broadly certain that war works precisely in the wrong direction as far as the heritable welfare of the race is concerned.

(2) This is accentuated by the well-known facts that specially brave bodies of men are selected for very hazardous tasks in which the mortality is often great, and that particularly brave men run unusually great risks. The Victoria Cross has been repeatedly awarded to some hero who lost his life in the exploit which won him the distinction. It is true that the fortuitous bulks largely in the casualties of modern warfare, and that there is often no sifting at all, but simply a tragic indiscriminate elimination, as when a battleship goes down. But where sifting does occur, it tends to be in the wrong direction, cutting off the very best. (3) There is another way in which war works in the wrong direction, by making life disproportionately difficult (and marriage often impossible) for the members of the race who are least readily replaceable. It is necessary to hold by the ideal of the state as a body politic—an organism—in which all wholesome men and women have their place and function; but it is plain enough that artists and discoverers, poets, and reformers are more precious than mediocrities. Indeed, the eye cannot say unto the hand "I have no need of thee", nor again the head to the foot, "I have no need of you"; but we are not equally irreplaceable! In the retrenchments that must follow a great war in which hundreds of millions of pounds are spent unproductively, the tendency is to economise most on super-necessaries, and unluckily on the finer super-necessaries, such as books, music, pictures, and higher education. This must tend to handicap most severely the more highly individuated members of the community. The highly skilled, whose work seems to be most readily dispensed with, will be pinched most; and they are certainly part of the salt of the earth.

WAR AND THE STRUGGLE FOR EXISTENCE.—It is a common belief that the evolution of living creatures has been due to the struggle for existence, and it is a common doctrine that what has worked so well among plants and animals should be allowed to operate in mankind. In making war, it is said, we are following Nature. As Bernhardi says, the decisions of war "rest on the very nature of things. . . . The law of the stronger holds good everywhere". This view reeks with misunderstandings which must be pointed out. (*a*) To begin with, biologists are agreed that the essential fact in evolution is the occurrence of variations or novelties. They furnish the raw materials of evolution and they are obviously indispensable. If they are to count they must be entailed or transmitted—heredity being one of the conditions of evolution. If they are to be more than beginnings they must stand the criticism of the conditions of life in which they have emerged—Natural Selection or Natural Elimination, which occurs in the course of the Struggle for Existence, being another of the conditions of evolution. Natural Selection prunes off the relatively unfit new departures, but the

struggle is not in itself the source of progress; it must have variations, or differences of endowment, to work on.

(*b*) Moreover the struggle for existence does not necessarily make for evolution. In many cases it thins without sifting, and that does not make for racial change. Out of 533 caterpillars of the large garden white butterfly collected by Prof. Poulton, 422 died because Ichneumon flies had laid their eggs inside them. This was serious thinning, four out of five, but so far as we know those caterpillars that escaped being victimised were no better than those that perished, so that there was no sifting. The indiscriminate elimination involved in thinning turnips with a hoe benefits the surviving individuals, but it does not improve the race of turnips. The only result of the struggle for existence that is of direct evolutionary importance is *discriminate* elimination, where the presence or absence of a particular character determines survival; or, what comes to the same thing in the long run, determines relative success in producing and rearing progeny. For it must be understood that the process of selection is often very slow, and even gentle in its operations. In some cases the struggle for existence forces creatures, without much or any organic change, to enter a new habitat or adopt a new habit. This again is not necessarily of much evolutionary importance, unless it is associated with a weeding out of the non-plastic, or brings secondary organic changes in its wake.

(*c*) We must also notice the obstinate confusion of thought, that selection in the struggle for existence must, automatically as it were, result in the survival of something desirable. What it results in is the survival (immediate or distant) of the relatively more fit to the conditions of life. It may work towards degeneration as well as towards progress; as is well illustrated by that evasion of the struggle for existence called parasitism—the door to which is always open. The liver fluke is "fit" as well as the sheep, and the tapeworm is as well adapted to its inglorious lot as the lark at heaven's gate. The survivors of discriminate elimination are the relatively fittest to given conditions—which might be hell.

(*d*) But there is an even deeper misunderstanding. In spite of many protests, beginning with Darwin's own, the idea of the struggle for existence has often been expressed in a narrow and wooden way. It is a fact of life much bigger and subtler than the words suggest, and we do well to repeat Darwin's proviso that the phrase was to be used "in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny". This full concept is far from being easy; Darwin himself confessed that he found it difficult to keep it always clearly in his mind. The phrase is a shorthand formula, summing up a vast variety of strife and endeavour, of thrust and parry, of action and reaction.

We thus need to look more fully into the facts of the case. Living creatures are continually being confronted with all but overwhelming difficulties and thwarting limitations. For some of these the living creatures are themselves responsible; for they multiply so rapidly that there is not enough of food to go round, or even not enough room to grow up in. We must recognise too that in the course of time "nutritive chains" have been established, one creature eating another, and that another, through long series. Beyond that there is the self-assertiveness of the vigorous creature. The lusty animal tends to be at times a hustler, elbowing its way through the crowd, though at another time it may almost surpass woman in its gentleness. Not less important is the irregular changefulness and inhospitality of the physical environment. In the crowdedness, the carnivorousness, and the unpredictable vicissitudes of the callous surroundings we see three reasons for the struggle for existence, and the fourth is to be found in the insurgence of life.

We have then an almost universal picture—insurgent creatures with a will to live and, surrounding them, all manner of baffling difficulties and thwarting limitations. Whenever the creature "answers back", reacts, asserts itself, girds up its loins against these difficulties, there is the struggle for existence. Where organisms do nothing or can do nothing—like the myriads of "sea-butterflies" engulfed in the huge cavern of a baleen whale's mouth—there seems no utility in speaking of the struggle for existence. For the central idea is that of "clash" between one organism and another or between organisms and the inanimate forces of Nature.

The struggle may be (1) between fellows of the same kith and kin, as when locust turns upon locust, and female spider on male spider, and stag upon stag, or as in the cannibalism in the cradle that occurs in the egg-capsules of the whelk. Or it may be between nearly related species, which Darwin illustrated by reference to the competition of brown rat and black rat—a reference to be considered, however, in the light of the facts submitted by Chalmers Mitchell in his *Evolution and the War* (1915). The struggle may be (2) between foes of entirely different nature, for instance between carnivores and herbivores, between birds of prey and small mammals, between heather and bracken on the hills, between different kinds of trees in the tropical forest. The struggle may be (3) between living creatures and the inanimate conditions of their life—for instance, between mammals and the winter, between plants and drought, between birds and the storm. Thus Darwin spoke of the struggle of a plant on the edge of the desert.

When we compare the struggle between fellows and the struggle between foes with the third form of struggle, which we may describe as between living creatures and "Fate", we see that in the third mode the element of competition has dropped out. Thus perhaps

we begin to see something of the subtlety of the struggle for existence. But we must go further.

(*e*) What has got into circulation is a caricature of Nature—an exaggeration of part of the truth. For while there is in wild Nature much stern sifting, great infantile and juvenile mortality, much redness of tooth and claw, and—even outside of parasitism—a general condemnation of the unlit lamp and the ungirt loin, there is much more. In face of limitations and difficulties, one organism intensifies competition, but another increases parental care; one sharpens its weapons, but another makes some experiment in mutual aid; one thickens its armour, but another triumphs by kin-sympathy. It is realised by few how much of the time and energy of living creatures is devoted to activities which are not to the advantage of the individual, but only to that of the race. Not that this is deliberate altruistic foresight, it is rather that in the course of Nature's tactics survival and success have rewarded not only the strong and self-assertive, but also—and yet more—the loving and self-forgetful. Especially among the finer types, part of the fitness of the survivors has been their capacity for self-sacrifice. And must it not be recognised as part of Nature's strategy that the individual organism, being kin-bound, realises itself in self-subordination to the interests of the species and may, in its self-forgetfulness, contribute to the larger welfare of the whole. Here may be gained a glimpse of one of Life's main axes, by which its movement is oriented, that which we call ethical in ourselves.

It is sometimes urged, however, that since evolution depends on individual variations and the sifting of these, we come back, in spite of ourselves, to the struggle between individuals. Thus Sir Ray Lankester writes: "The struggle for existence, to which Darwin assigned importance, is not a struggle between species, but one between closely similar members of the same species." As a matter of fact, Darwin assigned importance to many different forms of the struggle for existence: and although he heads a paragraph "Struggle for Life most severe between individuals and variations of the same species; often severe between species of the same genus", he did not bring forward many convincing illustrations. We do not, of course, deny that there is sometimes in Nature a life-to-death struggle between fellows at the margin of subsistence. What we maintain is that the decisive clash is often *not* between competing fellows, but between organisms and their surroundings, both animate and inanimate. It is often the environment that prunes. The fact is that the struggle for existence need not be competitive at all; it is illustrated not only by ruthless self-assertiveness, but also by all the endeavours of parent for offspring, of mate for mate, of kin for kin. The world is not only the abode of the strong, it is also the home of the loving.

The general thesis we are stating finds vivid expression in Kropotkine's *Mutual Aid*, and in Drummond's *Ascent of Man*, perhaps best of all in Cresson's *L'Espèce et son Serviteur*. Bishop Mercer has given a masterly statement of it in *The Nineteenth Century*, February 1915, which may serve as a useful correction of Huxley's famous Romanes Lecture on "Evolution and Ethics".

There is another point of great importance, that the sifting that goes on in Nature is necessarily in part determined by the already established inter-relations. Darwin laid great emphasis on the conception of the web of life—that Nature is a vibrating system of subtle linkages. No organism lives or dies quite to itself. Earthworms have made most of the fertile soil, and their lives are curiously intertwined with those of moles and birds, and even centipedes and ground-beetles; cats have to do with next year's clover-crop, and with the abatement of the plague, since ancient Egypt. Eighty seeds germinated from one clodlet on one bird's foot; squirrels affect the harvest, and water wagtails the health of the sheep. Darwin laid emphasis on these inter-relations partly because, as a naturalist in the keenest sense, he was closely interested in the actual life of living creatures as it is lived in Nature; and this helped him to discern how the sifting that goes on must always be upon the related threads of the web of life. There is progressive integration in Nature, linking lives together, complexifying inter-relations, weaving an intricate vibrating system; and the selecting or sifting operates not blindly or haphazardly, but in relation to what has been already established. The selection of variations is very far from being a chapter of accidents. The texture of the web of life is so fine that even an apparently trivial quality may be of vital importance in securing survival and success. Those variations are rejected which are incongruous with the established correlations of organisms. This idea is of great importance in regard to human life, where again selection is in part determined by the existing systems of linkages. Thus Man has in part replaced Natural Selection by social or rational selection. To a large extent it is his prerogative to make his own sieves. The non-dependable person increasingly tends to be sifted out by our social web.

War a Reversion to the Crudest and most Primitive Mode of the Struggle for Existence.—Socially regarded, going to war may be inevitable (in our present civilization), and, as above said, the only course open to a nation that would stand for honour, justice, and liberty. Ethically regarded, waging war may afford opportunity for the development of high virtues; but, biologically regarded, war is a reversion to that mode of the struggle for existence which is commoner at the lower reaches, namely internecine competition. We have seen that there are many forms of the struggle

for existence; we see no escape from the conclusion that war is a reversion to the crudest and most primitive form.

If this be true, it behoves us to mingle fear with our pride, for there are serious risks of slipping down the rungs of the steep ladder of evolution. As Mr. Theodore Chambers points out in his admirable lecture on "Eugenics and the War" (*The Eugenics Review*, January 1915): "It is in the actual environment of war, when excitement reigns supreme, that the most unexpected deep-seated instincts receive a stimulus. Lust, cruelty, and blood-thirstiness on the one hand, sympathy, courage, and affection on the other, seem to be intensified. War brings out into bold relief the intensest emotions of good and evil. War tears off the decent garments of custom, and leaves the soul naked."

Among non-combatants, too, there is apt to be deterioration as well as ennoblement. If war, in spite of being illumined by heroism and endurance, in spite of being embellished by the achievements of science, is in essence a return to the crudest form of the struggle for existence, preoccupation with war is full of danger. What sowings of dragons' teeth there must be in every war, however just the cause; is it weak to be afraid lest in the crop that springs from them there may be something less welcome than armed men? The past lives on in our present; the ape and the tiger die hard; there is always, as Tennyson said, a dread risk of Reversion "dragging Evolution in the mud".

To sum up, man is fortunately not shut up to searching in Nature for guidance; he stands apart, with an instructive history. Yet if he looks carefully enough he will find Nature has another message besides—"Each for himself, and elimination take the hindmost; contention is the vital force; and careers are open to talons as well as talents." There is another message—much harder to obey—of subordinating individual gratification to welfare of the species. And again, if Man does insist on following, as in war, the mode of the struggle for existence in which rats can excel him, he must not delude himself with the hope that it will necessarily result in the survival of the fittest in any progressive sense. The most desirable types are apt to get sifted out, leaving the race impoverished.

Our argument is that *from a biological point of view* war must ever be regarded with anxiety, since it makes for the impoverishment of the race by sifting out a disproportionately large number of those whom the race can least afford to lose; and that, far from being in full accordance with Nature's message to Man, it is a reversion to the crudest and most primitive form of the struggle for existence, and therefore to be regarded with peculiar fear.

If war brings racial impoverishment, as it seems bound to do, what counteractives are possible? (*a*) There may arise a more marked disapproval of selfish forms of celibacy and a stronger

encouragement of chivalrous marriages. (*b*) There may spring up a freshened enthusiasm for all-round fitness and a high standard of health, and it must be granted that all improvements of "nurture" in the widest sense are to the good as long as it is clearly recognised that veneering does not make bad wood sound. A nation's losses may strengthen a resolution to face the national wastage due to such diseases as tuberculosis; and to improve the conditions that are in part to blame for other evils, such as syphilis and alcoholism. (*c*) Some clearer understanding of what selection means may lead to a scrutiny of the retrenchments which the costliness of the war always necessitates. To economise upon the nobler super-necessaries means crippling such super-men as painters and musicians. We should try pinching ourselves in our comforts before we begin starving our souls. But talking is easy and doing is difficult. (*d*) What the biologist is most concerned with is the natural inheritance of the race, which is fundamental, but the human outlook is wider than the biological. Man is concerned with his social heritage, which is supreme—with, for instance, his traditions and ideals of honour, veracity, courage, justice, and good will among men. Hence ever more clearly appears the urgent need of planning and mobilising truly evolutionary progress, with its nobler rivalries.

THE CASE FOR EUGENICS

The industrial age, with its increasing progress of business and manufactures, naturally soon developed their appropriate complement of increase of wealth and population; so that its characteristic economics and corresponding politics long seemed beyond question. Criticisms, however, have long been arising of the sufficiency of all this progress, and even of its efficiency at best; but only those from biology here claim consideration; and of these there are mainly two. First there came the shock to economic optimism nearly a century ago, from the depressed, disease-tainted, and short life of working children, women and men, and with some measures accordingly; whence largely a substantial advance in public health. And this not only through the application and advance of medicine, but also largely by recognition of the association of ill-health with bad housing and slum conditions. Hence the sanitationists, with their standard plans and regulations—all still in progress, and with diminished death- and disease-rates encouragingly. And though the cost of these changes first shocked would-be economists, and so needed moral motives and social leadership to carry them out in practice, the resulting economic gains, both by diminished loss of time through illnesses, and by lengthened years of productive efficiency, were increasingly found a main factor in industrial

progress and its pecuniary returns. Hence progress on these lines continues; so that its comparative slowness, complained of by its advocates and leaders, is more from social and mental inertia than from economic opposition.

Next after the Sanitarian school has appeared that of the Eugenists. Their criticism also recognises defects in the industrial age; but especially scrutinises its long boasted increase in population. For it finds this "progress" not simply falling short of evolutionary ideals, but even too much below the normal level, and this whether biologically or psychologically considered. These propositions are founded on observation, and verified by statistics; and these viewed as an incipient qualitative census; this much more thorough-going than the too simply quantitative census, with its optimistic tradition. The results of eugenic surveys have been very far from optimistic, indeed alarming; those who know them best at times even say appalling. These are sadly confirmed by the official returns of governments—especially in times of war, and both for this country and America, since war demands a qualitative selection of young men suitable for bearing arms. Hence the national shock, nearly a generation ago, from the enlistment returns from the Transvaal War; and recently to America, from the amazingly low results of its more thorough testing of 2,000,000 volunteers, though themselves a so far selected group.

The eugenist has thus justified his case; and he goes on doing so, ever more thoroughly. He shows that our peoples, apparently so advanced and advancing—so far as quantity of wealth and population are concerned, and in various forms of culture too—show also no little of going backwards, in the fundamental qualities of breed-values. And, more alarming still, he shows that the rate of reproduction of the mediocre types of population—and even of those more or less sub-normal, alike in organic, in mental, and in social values—is now, under present social conditions, proceeding much more rapidly than that of the more normal; while these again increasingly tend to outnumber the super-normal in any or all of these three above-noted values, bodily, mental, and social. If then it be also a statistical fact—and no one has contradicted it—that 25 per cent. of the existing generation are producing 50 per cent of the next, the increase of inferior family breeds, and the reduction of superior ones, is surely ominous for the social future, and that before long. Man is thus certainly "not demonstrating that he can remain permanently civilised". Even the maintenance of the social heritage, let alone the furtherance of its best activities, cannot but increasingly require a better selected minority for direction and guidance, and also a higher standard of life-efficiency throughout the community as well. In short, the eugenist here breaks with conventional doctrines as that "all men are created equal"; since he sees they arise, develop,

and evolve very unequally. Yet he does not thereby revert to the aristocratic exaggerations, errors, and consequent decadences of the past.

Long ago, when some optimist was praising the traditional economic ways of success and of getting on in life, as even into the peerage, Huxley grimly remarked: "No doubt very fine for these classes; but how about getting their incompetent members and successors down again? Is not that often the greater difficulty?" Every true eugenist must admit that he is bound by his doctrines to tackle that question too. His goal may thus be described as towards true aristo-democracy, and also true demo-aristocracy; yet not by going back upon "equality of opportunity", but through yet more thorough provision of this; and much through seeing to its true selection as well. That "the tools are to those who can handle them aright" is neither a proposition of old social privileges, nor of later political election. It is a high calling indeed, and an election which should become sure: yet open, as Christianity at its best, before all races, all classes—"Barbarian, Scythian, bond or free". Democracy and freedom have rightly affirmed their claims to seek and choose their best leaders, and to find and choose yet better when they can: so here is a further help for them to do it; and a further incentive, not only to be worthy of such leadership, but to see to producing more of it anew and among themselves.

How then put these doctrines more clearly before the community—and even get their applications into it? Again mental inertia blocks the way. Intensity of appeal is thus needed; so here we may slightly condense a passage from a recent vivid American presentment of the case for Eugenics (A. E. Wiggam. *The New Decalogue of Science*, London (Dent), 1924), and in a volume addressed as an open letter to "H.E. The Statesman, Executive Mansion".

"The first commandment of science to statesmanship is the duty of eugenics. 3,000 years after the Hebrew statesmen incorporated eugenics into their civil and canon law, 2,400 years after Plato gave it formulation in political philosophy, 2,000 years after Jesus reinforced its moral and religious sanctions, 60 years after Darwin, 50 after Galton, 30 after Weismann, and 20 after Mendel, I seem to hear you inquiring, in vague, mystified wonder, 'What *is* Eugenics?'

"Perhaps I can best answer by pointing out first what Eugenics is not. Eugenics is not free-love, not sex-hygiene, not public health, not trial marriage, not a vice-crusade, not pre-natal culture, nor physical culture, not enforced marriage, not killing off the weaklings, not a scheme for breeding supermen, or producing genius to order, not for taking the romance out of love, not for breeding human beings like animals, and not a departure from the soundest ideas of sex-morals, love, marriage, home and parenthood. . . . Turning to the positive side, and modernising Galton's definition, 'Eugenics is the study of all those agencies that are within social control, which will improve or impair the inborn

qualities of future generations, mentally, morally, and physically. These are biological and psychological, chemical and physical; economic, social, and political; educational, moral, and religious.' Control of these great agencies, if wrongly directed, will impair man, and if rightly directed, will improve him. You cannot enact Eugenics—it means a new religion, new objects of religious endeavour, a new moral code, a new kind of education, a new conception of many of life's meanings, and of the objectives of social and national life, a new social and political Bible, a change in the very purpose of civilisation, and the fundamental *mores* (life-ways) of man. It means the improvement of man as an organic being, and that the enhancement of man as a moral being. It means that the enhancement of man's inborn capacities for happiness, health, sanity, and achievement shall become the living purpose of the state. . . . It is a change in the perspective of civilisation, character, and life. It is a new kind of humanism. . . ."

We must leave now this vigorous platform statement, and even before its climax of appeal, for aid from publicists and men of letters, to turn to the presentment of the case by one of its most weighty exponents, Major Leonard Darwin (*The Need for Eugenic Reform*, London (Murray), 1926), who speaks not only with the conviction and purpose of continuing his father's work and impulse as he would have wished; but also with the experience of many years' presidency of the Eugenic Education Society, in successorship to Galton himself. "Eugenics consists in the utilisation of knowledge acquired in the study of living things, in order to promote the progress of the race." So following this, come careful chapters outlining this knowledge, and impartially discussing the conclusions and the lines of action to which it appears to point—all of which well reward reflective reading.

For more concrete details, however, a manual of the subject is needed, with summaries and illustrations (conveniently Popenoe and Johnson's *Applied Eugenics*). The preponderant importance of "Nature over Nurture"—i.e., the importance of good hereditary stock over that of good environmental conditions, is justified at the outset, with explanation of the contribution and influence of Weismann's germ-plasm theory; while the enduring significance of heredity is illustrated from genealogies bad and good, from ordinary cases to the extreme ones. Witness that of one Juke, born in 1720 in the fine locality of the New York "Finger Lakes". His two sons married in their time five degenerate sisters, from whom have been traced, through six generations, up to 1877, no less than "about 1,200 persons, of every grade of idleness, viciousness, lewdness, pauperism, disease, idiocy, insanity, and criminality". More striking still, a fresh monograph of the same family, made in 1915, less than two generations later, enumerates no less than 2,820, of whom half were then living; and who "on the whole still show the same quali-

ties, even when not handicapped by their bad family name, and despite being surrounded by better social conditions". More significant still is the example of Kallikak,

"a soldier of the Revolutionary war, from whose first son by a feeble-minded girl, have descended 480 individuals, of whom 143 are known to have been feeble, and only 46 known as normal, while the others are unknown or doubtful. After the war, however, Kallikak married a woman of good stock; and thus with 496 direct descendants, among whom only two were alcoholic, and one known to be sexually immoral; while the others have been doctors, lawyers, judges, educators, traders, land-holders; in short respectable citizens, men and women prominent in every phase of social life. These two families have lived on the same soil . . . yet the bar sinister has marked every generation of the one, and has been unknown in the other."

Probably the culminating illustration as yet for Eugenics on the credit side is given by the descendants of the famous Jonathan Edwards; "of whom all but 1,400 were recorded by 1900—of whom 295 were college graduates, and 13 presidents of our greatest colleges; 65 professors, besides many principals; 60 physicians, many eminent; 100 and more clergymen, missionaries or theological professors, 75 officers in army and navy; 60 prominent authors and writers (135 books of merit, 18 important periodicals edited)." Similarly in law and politics and administration, up to many judges and ambassadors, mayors of cities, senators and governors of states, even to the Vice-Presidency of the U.S. Again in business, and on the highest grade—presiding over great industries, banks, insurance companies and the Pacific Steamship line, and no less than 15 railroads! "Almost if not every department of social progress and of the public weal has felt the impulse of this healthy and long-lived family. It is not known that any one of them was ever convicted of crime." Here surely is the record for that superiority of the sons of the parsonage and the manse which appears in such strikingly high proportion in the British *Dictionary of National Biography*.

Of course all the above pedigrees are record ones; and it is obvious that each type, good and bad, must have been maintained and accented by corresponding matings. Witness again the sixty recorded good musicians of the Bach family—or for a modern English example, the Darwin, Wedgwood, and Galton alliances, since so well illustrating how eugenic superiorities may be combined, and towards production of many exceptional men of talent, and even genius: so likely to be long continued, with talents maintained and developed; and even the strains of hereditary genius appearing anew. Verifiable kindred cases are ever increasingly disclosed, albeit of course generally less rich in numbers and in quality; yet amply enough to justify the wide resumption of family pedigrees, and towards volumes of "Eugenic Families" more socially significant and

exemplary to wise ambition than "The Peerage", though that too would yield a substantial proportion worthy of such scientific record. Thus the old and natural interest in pedigrees would be democratised and aristocratised anew; and so be rid of its burden of mere snobbery. "The Golden age of Genealogy has yet to come"; indeed, it is now beginning, and with a scrupulosity and thoroughness surpassing even that of royal families in the past, and a graphic completeness of notation surpassing all heraldic quarterings. Yet no longer interpreted in the old and still customary sense; for merely by the line of ascent which carries the family name, "practically nothing is known" from the truly genetic viewpoint. For any of the other three grandparents may be dominant in you or me, as any of the sixteen of theirs, and so on; with increasingly minute chance accordingly that your direct descent from the Conqueror, as still less mine from Kenneth Macalpine centuries earlier, is in any way effective in us! Hence, too, where descendants of a number of such selected ancestors have mated together for ages, as among leading royal families of Europe, the result in talent or genius is by no means so distinguished as was constantly hoped. Still, from a careful genealogic monograph of these families—and that fortunately by an American investigator, detached from all European loyalties accordingly—the fact appears, for their after all moderate numbers through recorded ages, that their percentage of recognised talent, and even that of occasional genius, is notably and undeniably higher than usual: witness the Medici, the Stuarts, etc., etc. Yet democracy can now do better, as the above-chosen examples show; and the more since it is less weighted down by mere *mariages de convenance* such as have too often deteriorated royal strains, and sometimes even to ruin.

Enough, however, to show that eugenists are not afraid of scientific work; and that they are not to be content till they have extended its inquiries throughout all classes of their peoples. So what now of the desired applications? Too numerous for more than briefest mention here. First of all, the damning proof of the dysgenic results of war; and of the last Great War as extreme case, for Western Europe, with consequent insistency for peace accordingly. Yet peace in no mere passive sense; since thus involving urgent and speedy consideration of ways and means of increase of the eugenic types; and, frankly too, the decrease of the dysgenic breeds, since at present it is the former which ebb, while the latter flow. Every form of existing social, economic, and political endeavour thus needs criticism from this eugenic viewpoint, so essential to the continuance and improvement of breed and civilisation alike, and these from villages to nations, even to races. So not only eugenic papers but volumes are ever appearing for each aspect of the subject. The improvement of sexual selection and mating is often urged; and these from simplest everyday choice, by good looks and points

generally, to fullest inquiries, as for organic vigour, and up to ancestral longevity, similarly for mentality and character; each and all tending to replace the long customary insistence on money or social status alone, save when backed by true achievement. Here, then, the practical ideal is to make "ordinary" matings be considered, not less but more seriously, then have patrician and royal ones. Immigration selections and restrictions, racial restrictions also, have not only been much before the American mind, but are now—however roughly—embodied in its policy. The like passage from thought to action is in progress for many communities, witness segregations of the defective and diseased; and in some States even sterilisation of certain criminals, those of sex especially, but not exclusively. Birth control is, of course, in active progress in Europe and America alike. And though this be so far often dysgenic, since so much resorted to where least desirable, the post-war abatement of European trade, and the nearing of agricultural limits and yields for still increasing populations, are alike plainly increasing this; it may be even before long more and more widely. Yet this can be no panacea; and it is of importance here to note that the whole modern inquiry of Eugenics has arisen and its policy been in development, long after birth-control has been practised and advocated throughout Western Europe and America.

The eugenist's essential doctrine and endeavours towards race-improvement, and this not only organic but psychic also, are so fundamentally excellent, that it is no small delay of social progress that his teaching and his efforts progress so slowly; once more, however, we can but plead that he extend these as not only as regards woman and marriage, by actively progressive and constructive measures of encouragement of the best matings, and so even as one of the best accelerations of public sentiment towards the discouragement of the inferior and the positively evil ones.

With extreme family histories and their biographies before us, we tend to judgments strict and stern; hence many eugenic writers have too simply re-expressed in their writings the sculptures over so many medieval church portals, with the damned falling, the blessed rising, respectively to left and right of their inexorable judge. But in ordinary life, and its inheritances, the matter is not quite so simple, as the Church's gentler traditions show, and as criminologist and psycho-analyst are again learning and teaching (and even from lives which seemed worst fallen). And so, too, as to families and breeds; for, with all respect to such a family as Jonathan Edwards', who has not seen inferior and even defective individuals appearing in families otherwise eugenic of best? Many years ago, when eugenists were still callow in experience, and thus thinking their problems simpler, their applications easier, than now, there appeared a forcible reminder from one of the best and fullest of then

living observers and interpreters, and of tainted families especially, Sir Arthur Mitchell; who pointed out, for humanity, what shepherds know even among their best breeds, and of picked parentage, that there may still appear what in Scotland they call a "shargar", a miserable deteriorate or degenerate. And in our own experience of life, have we not each been once and again surprised and perplexed by such occurrences? Are such cases simply reappearances of some long-latent defective strain—or are they new ones; and if so from what causes? In sheep this worst lamb is often youngest; and in humanity the like sometimes too; yet at times the youngest may develop best of all. Here there are lines for fuller investigation, each far from easy.

EUGENICS AND EUGAMICS.—Eugenics, as an advancing branch of science, is not getting on so badly; but how among the great public to whom it refers and seeks to appeal? They are as yet mainly indifferent: but all sciences, especially social science, yet biology also, are too much in the like case. What is wrong? In our own way, we are all out to be fishers of men, but we are not catching them, or at most a few here and there; but never a net is full as we would desire. The first feeling and tendency is to blame our public: but the more reflective angler learns that if he does not catch his fish, there is no use blaming them; it is himself he has to criticise. His place or time may not be suitable; and his bait or fly not the right ones; his handling may be at fault, and so on. And the like for every art, and its science too. Yet the fisher has also to go back to the study of the fish, and look into their ecology to find his clue.

What then of the public, on whom the eugenist would fain act? Are they not often alarmed rather than attracted by some of his proposals, the more they hear of them? Do they not feel a certain harshness in the presentment of some of its teachings? And still more in those of the bold American eugenists, who have brought sterilisation into practice in their States? Do they not feel something of what Bertrand Russell says right out, that "if eugenics reached the point where it could increase desired types, it would not be the types desired by present-day eugenists that would be increased, but rather the types desired by the average official". And if eugenists doubt this, let them explain more fully on what kind of State they would found their hopes, and see whether it be not more like what a new Kaiser might give us, rather than any order admitting of human freedom. How often has selection "for reasons of state" been Herodian; but never as yet Magian. Too much, so far, the popular impression of eugenists (though unjustly so far as its best expositions are concerned, as from Major Darwin's balanced statement or Dr. Saleeby's glowing one) is well nigh to discouragement of that betterment of the environment, in wealth

and health, in beauty and happiness, from homes to regions and villages, towns and cities, which they are beginning to think of as required. And as for the insistence, however biologically and psychologically sound, on selection of the fittest families, and towards racial betterment accordingly, they remain distrustful. And here not without some justice. With real respect for the gist of Francis Galton's *Hereditary Genius*, can one avoid sometimes smiling at the naïveté with which successful lawyers and business men and more are mentioned as transmitting success and prosperity to their sons, with little mention of their social advantages as compared with sons of the people! So would not eugenists profit by a book like Veblen's *Theory of the Leisure Class*, which seems seldom known to them? Again, are eugenists abreast of Mendelian progress, and of that of the Freudian school? Individually often yes: but fresh eugenic presentments seem needed.

Return, however, to the public, say the man on the bus, the woman inside. He is reading the evening paper, for its outdoor interests, from sport to weather, and for his business interest, thereafter political matters, accidents and minor incidents, snippets and jokes. But when a woman takes to the papers, births, deaths, and marriages often take the first place; and then the personal news, from doings of the royal family to the latest passional incident, as of divorce or crime. As commonly as a young man chooses the paper with most news of sport, so the young girl turns as instinctively to the story papers; and among these not usually those of adventure or detective marvels, read first by the men-folk; those of her choice involve the love-theme, fundamental to her organic anticipation of mating. But these papers have practically no articles on eugenics: how shall we get their editors to desire them? How give the subject a fresher and wider appeal?

The eugenist may reply and so far truly, that while man normally mates for love of the woman, and she so far for that of the man, she has also a far deeper-lying longing for the child. Granted: yet this is as yet more implicit than explicit: so his science does not appeal to her so far. So much then for the fish, and why they are not taking. They are interested in expressing their lives, in expliciting their immediate dreams, and not readily in restraining either their own or those of others, as the eugenist cannot but desire.

What then is to be done? The eugenist must abate his hopes from the State, at any rate till he has converted a sufficient public. And also his conviction and feeling of class, so ingrained from home, school and university alike, and career as continued afterwards. In the London or older Oxford atmosphere (which reach far beyond) this class-feeling readily colours eugenic conversation: and the element of justification appears as we roam the surrounding villages; for there depressive influences and selections through a long past

are manifest. But in France or in Scotland far less: thus writing now in the latter, and through life in fuller touch with their villagers than London or Oxford as easily afford, we honestly fail to see anything like the same degree of difference, biological or psychological, in people of normal life; in fact, we can make out no distinct inferiority of our rural neighbours to our academic and otherwise cultivated ones, or in the potentialities of their families either. We see the selection of picked individuals, and the (more serious) emigration of able families, which even if not yet manifestly lowering the value of the village populations, can hardly but be in that direction. To maintain and improve those values is obviously the eugenic need: but who as yet sees clearly enough what social changes are needed, much less to devise them?—even then, with what prospects of execution?—and after all, with what certainty of result? Here surely the sociologist is needed, and with his surveys carried deeper. The best novelists are here our exemplars, and will do better still as our scientific questionings reach them.

With the preceding difficulties and more, it is no wonder that eugenics makes slow advance, even as doctrine, let alone as practice. So again, what is to be done? Here at least is one practical suggestion, far from new yet too little developed; and promising more consideration, and even trial, than it has yet had. It is not towards abating eugenic interest, since eugenics cannot be too fully prosecuted; but of increasing our *eugamic* interest, that in good matings, such as we can truly congratulate, and with wishes genuinely hopeful. Does the eugenist reply that he has done that all along, and does so still? Doubtless yes, in thought and appreciation: but as yet little in practice worthy of his knowledge and sympathy, towards aiding the process of mating, and towards better, and best; a problem daily re-opening in the present, and on which successful improvement towards the eugenic future so immediately depends. Is it replied that scientific societies do not enter practical life? Eugenics is practical; it is the highest branch of genetics in particular, and of biotechnics in general: so it simply has to strive towards experimental realisation of its aims, or abandon them. Is every Eugenic Society then to become a "matrimonial agency"? As a matter of name, of course not: but as a matter of fact, yes; and the more the better. Without using that vulgarised name, what else is so fundamental to "the London season"? So too, every gathering of young folks, for an excursion and a picnic, for an afternoon tea let alone an evening dance, and still more for presenting a play, is doing that already. Every university of mingled sexes brings about some percentage of pairings; and proportionately still more a summer school, a field club excursion, a collective tour with its fresh and unfamiliar groupings; likewise a church society, a mixed choir; and yet more again, a civic pageant or a masque, with its larger numbers,

both of players and of audience, and the former more carefully and widely selected, without reference to their usual social groupings and separations, and thus generally for these very qualities the eugenist desires to see transmitted towards the future weal. Other scientific societies can hardly but have their social limitations: but the eugenists have all the social world before them whence to choose: and so may again help to repeat the best pairings of the past, even to bringing Cinderella to meet her Prince, and the knightly scullion his Princess. But their needed Kingdom? After all, that on the material side was often but a small one; and so may be this. Though material dowries are no essential part of eugenic policy, the wedding gifts so universal, albeit so largely wasted, might be increasingly influenced by eugamic eugenists towards that real usefulness in the difficult start in life, from which they have only lately been diverted to trifles, often not even decorative. The real endowment, eugamic and eugenic alike, is, of course, in the vital values of the young people themselves; and these as further evoked by the love which unites them: and a brave young couple often desires no more. Yet later events often prove they needed more: so here arises that question of finding employment, which is not only so difficult and ominous in the labouring world, but even more so for men whose aptitudes, and corresponding social values, are in lines less easily followed than those of the predominant mechanical and pecuniary culture, or even those accessory ones which such standards can employ. If so, our eugamic practice has frankly to face such difficulties; and not only by considering special cases as they arise—even if such can be truly recognised, no easy matter—but essentially by turning again to those general social studies and endeavours among which eugenics has arisen, and utilising all these can yield towards increasing appropriate employment. So a sort of "Labour Bureau"? Again in name, no; in fact and of a kind, yes.

In every practical discussion, the question of funds and resources soon arises: hence eugenists have often already pled for endowments; but they do not appear to get them; nor will they, till the eugenic faith is more widely and fully accepted. Meantime, however, we have each our own occupation, and expenditure, so even if we can find no openings in the one, can we not give some little employment through the other: as pictures are thus sometimes bought. Influence every one has, in some measure; and co-operative organisations towards all manner of useful ends arise and increase. Our eugamic endeavours need to be strengthened along with employment of social service. Here, of course, we are far from suggesting mere eleemosynary ways, albeit something of foster-parental ones. Let these young couples rely upon themselves as fully as may be; yet why not aid them towards association, conveniently of civic or appropriate regional range, as (say) "The Brides of 1930–'31".

and so on? College class organisations by years are already familiar; county and clan societies abound, and more. Such new organisations acquire solidarity in many and increasing ways through their periodic meetings and outings, and thus sometimes with incidental advantage, towards survival of fit pairs, and families accordingly.

Are we here becoming "Utopian"? Better mating, better breeding, better homing (still too little considered in "the housing problem", albeit developing, as in garden villages at their best)—these are all Utopian, since progressively realisable, and thus Eutopian in very deed.

Such furtherance needs more definite emotional urge; for on this, action not only, but science too, deeply depends. Where shall we find this? It is all around us, in current literature, in the novel-writing and story-telling which head reading lists, and with poetry coming forward anew. Little of this is clearly eugenic: yet how much, indeed wellnigh all, eugamic? Young lovers must first find each other, and get over their difficulties of mating before the family question can be much realised; and every novelist brings them through these crises. So must the eugenist freshens his present reading, his observing, his advising, by the impulse of romance, of drama, and of poesy, each at its sympathetic best. Eugenics will thus advance in insight and knowledge, and find the widening consideration and influence it still lacks, through beginning anew with eugamics. "'Tis Love that makes the world go round!"

Recall for a moment the potent historic significance of Jean Jacques Rousseau, above all as main inspirer of modern individualism, with its freedom and democracy. And this not only as intellectual ferment of his time in France, and even in America, to its Declaration of Independence; and thus for the French Revolution, and thenceforward for the later reductions of the old aristocratic order over continental countries and in Britain as well. The great impulse to educational freedom given by his *Emile* has likewise continued to bear fruit. But next ask why he tore each of his five children from their unhappy mother as they came, and pushed them out of sight for ever into the revolving box of the Foundling Hospital, where presumably most (or all) died. This his biographers record with regret, and as the worst stain upon the deeply blemished character and career he himself for other matters so frankly confesses. But do they not miss the real interpretation—that of the ruthless logic of the prophet of progress through individual freedom, in thus offering up the extremest imaginable sacrifice, that of his own flesh and blood; so expressing, as fanatics of earlier faiths have done for their beliefs, and in no less terrific and symbolic rite, that would-be liberating evangel, of Individualism to the uttermost, of which he was the culminating exponent, and to applications undreamed before, even in his old home-city and republic of Geneva.

For has not this theory—of society disintegrated into its Individuals (with its unseen consequence, of these becoming more or less "dust of the State" accordingly)—characterised industry and economics, with their resultant politics ever since: and correspondingly has it not been a main dissolvent of the family? So, in a single image, Rousseau more or less put us all into the foundling hospital; and Eugenics is the foremost example of a really scientific endeavour to get us out of it. How so? By its recall of us to our families again, and to kin and kind once more. And this now more fully than even of old; since with conjugal choice and responsibility shown as deeper and more sacred than even law, morals, and religion had realised before. Thus also towards soul as well as body increasingly protected or purified from all such deep taints as those Rousseau confessed as personal, but which the Freudians are now tracing, first in their city cliniques, but thence throughout human life; and yet more searchingly than have even confessors of sins and theologians of original sin, both separately and together. Eugenics thus calls for renewal of family responsibilities, which our present parental dependence on our State schools, or yet more on artificial orphanages as Public Schools, can no longer so lightly absolve us from.

Are the gains through liberation of the individual then to be sacrificed? On the contrary, developed; and even beyond Rousseau's hopes and dreams. For now each individual is seen as of yet more significance than he knew, since not only as complex life-product of the past, but as a potential creator of the future. His ancestry is full of significance; and his very presence in life to-day is evidence of the predominance of many good survival-values maintained, despite whatever ancestral and even personal limitations, or taints of evil. These may—indeed, now only too frequently do—make him if not even wholly unsuitable, at best less desirable than others for our now realised responsibility to the society of the next generation, and coming ones, as one of their ancestors: and if so, there is no denying hard fate here; and this even to segregation in the extremer cases.

Yet that is not the only possibility of selective restraint. Since the war, our nearest neighbours, as its greatest sufferers, pass commonly the rueful saying: "Every Frenchman is ready to die for his country, but he does not know how to live for it!" But the eugenist is obviously ready, and with not a few fundamental elements, towards the needed answer. There have long been evidences of arousal to the importance of the population question in France, and though so far especially as regards quantity, yet with beginnings towards quality too; so the great opportunity of eugenic selection among the nearly two million foreign immigrants since the war has not been wholly missed, though too little utilised. American and other immigration laws also show endeavours towards eugenic

policy; though all as yet in the rough. Still, in these days governments are becoming less unwilling to adopt measures suggested by science; so it behoves the eugenists to be getting these clear and ready.

Such movement needs heralding, and this by literature; for impassioned writers often pioneer and influence the opening future by their forecasts of it. Thus a generation ago and more, when a too simply progressive notion of evolution was more general than now, but degeneration and pathology, with heredity also, were being also eagerly discussed, Zola's novels advanced in range and grasp, and especially as regards heredity, witness the Rougon-Macquart Series, culminating in *Dr. Pascal*. Similarly nowadays we have Galsworthy's *Forsyte Saga*; and other authors are on kindred lines. Hence too Mr. Wiggam's public appeal for eugenics above cited culminates in one to our leading writers to help—and coming ones will surely more and more do this. For not only in extreme cases of bad and good heredity, like those above chosen, but in the masses of material which eugenists can now offer, and in the fresh observation ever open around us, there is ample scope for a fresh *Comédie Humaine*, even more vital for our day than was Balzac's for his time. Such a new writer would be read more widely than even his predecessors, and with inspiration to rivals and successors; with these not only freshly re-interpreting the large-scale history of the past, and the movement of the present, but creating for every city and region a new "literature of locality", and that increasingly suggestive for other regions as well. In a public thus aroused and interested, what promise for eugenics, with its better re-weaving of the web of social life!

NORMAL AND SUPER-NORMAL TYPES: "GENIUS".—It is an old saying of Emerson—towards whose philosophic and poetic insight of evolution the thought of science is only now ripening, that "all the facts of the animal economy—sex, nutriment, gestation, birth, growth—are symbols of the passage of the world into the soul of man, to suffer there a change and reappear a new and higher fact". This, indeed, outlines what in previous pages we have been striving to express in part. As psychobiologists we have to search out more fully the conditions of such evolutionary progress, and with experimental endeavours, as far as may be, to initiate fuller realisations of them. For as these conditions are discerned, we see that what have appeared but rare and exceptional manifestations of humanity—whether as marvels of organic perfection and beauty, or of "gift" or "genius"—are to be understood as flowerings of life, and thus essentially normal. It is not their occurrence, but their rarity which has to be explained. And this not exclusively, as with our unsuccessfully flowering plants, in terms of inferior nature and

quality of seed, nor yet of defective culture-conditions, but both together: and so in the complexities of our human life. Their criticism is of old date, but their re-investigation is again before us: it must be long and difficult, to many discouraging, yet not impossible. The current renewal of the ancient selection and control over the plants of cultivation, the animals of domestication, is not one of failure, but of increasing evolutionary encouragement; and so for our own species are the advances of medicine and education. On many lines then we have encouragement: our present knowledge justifies further search and thought, and with purpose and endeavour towards applications. Knowing broadly and increasingly our long ancestry—from sub-human types to human, and of these to and through many civilisation-phases, with their heritages each in its way of significance and value, and in each stage with acceleration in time—we cannot despair of abating the associated ancestral burdens, and of more and more advancing from man as he has been, and now is, towards man at his best.

BREEDING TOWARDS IDEAL TYPES.—Every one knows how skilled and successful have been the old-world breeders, as from Arab horses in the past to racers to-day. And though the modern Mendelian breeders now get more assuredly and rapidly to the types they work towards, they all alike, as similarly their fancier and farmer clients, have always had clear and well-defined ideas as to the exact "points" and qualities they wanted, and of the general type to be aimed at as well. But this amounts to saying that through long ages past (the best Arab pedigrees are accepted as authentic), these apparently homely and practical matters of rural business, and towards profit and use even oftener than pleasure, have been uniformly planned and conducted in terms of *ideals*: clearly imagined and precisely formulated organic ideals, both in general and in detail, for each and every important animal and plant dealt with. Is it then conceivable that the ideal of human good-breeding only came in with recent eugenics? Were the really long ancient pedigrees, as from Egypt and Israel of old to China up to this day, the mere matters of family or personal pride our relatively briefer ones in Europe have degenerated into, as did the art of animal and plant breeding so long with them? Is it not a more reasonable hypothesis, that of old human selection went on with much at least—if not even more—of the care and experience and insight from which have come our domesticated animals and cultivated plants, each and all of them prehistoric? When anthropologists are never done discussing selective pairing practices and restrictions, like exogamy and endogamy in ancient peoples, which our modern "myth of savagery" still teaches most of us to scorn, what close and keen attention to breed do these and the like not point back to, when they were being established long ago? This passage from Theognis (about

550 B.C.) is often quoted by eugenists, but is well worth recalling once more:

> We look for rams and asses and stallions of good stock, and one believes that good will come from good; yet a good man minds not to wed an evil daughter of an evil sire, if he but give her much wealth. . . . Wealth confounds our stock. Marvel not that the stock of our folk is tarnished, for the good is mingling with the base.

Plato would have the State intervene to mate best with best and worst with worst; also that the families of the former should be large, and rewarded by the Government, while those of the others should be put away. Aristotle also developed the idea on political lines, as more interested in economic than biological aspects of marriage; but he held firmly to the doctrine that the state should feel free to intervene in the interests of reproductive selection.

All historians agree as to our vast losses of the heritages of ancient thought and skill from past civilisations; and here is surely one of them. The "dark ages" into which Europe fell with the destruction of Greek and Roman culture by the barbarian invasions are commonly thought of as long past; but, as matter of fact, is not their darkness still upon us—for each and every vital thought and achievement which we have neither recovered from the past nor yet worked out anew for ourselves?

It is well indeed to do both, and as regards the greater civilisations especially. Thus we have just seen how the Olympian Gods express life-phases akin to those of embryology and ordinary anthropology; and though our advances towards animal and plant breeding are now more skilled and sure than were those of our predecessors, we may still have something to learn from these, as surely for humanity.

EVILS IN ORGANIC LIFE.—How far can the preceding outline of human and social evils contribute towards the understanding of the difficulties of organic life? A main one is that of finding subsistence for increasing population, and this as checked accordingly. But to this difficulty of Malthus we have the qualified yet definite Darwinian optimism, of progress by natural selection; and also Spencer's insistence on the rise of individuation in the animal world in association with a diminishing rate of reproduction—so that here are elements of consolation for the (sometimes surely excessive) fears of eugenists. (See sections on Heredity, Eugenics, etc.)

As we have already pointed out, animal life shows but little of disease, compared with man, though enough for substantial beginnings of comparative pathology. Yet when these are viewed from the more general viewpoint of variation in general, a certain element of hopeful interpretation arises even here. Thus the natural rise of temperature, observable in cold-blooded animals in activity,

has become equilibrated into permanence in warm-blooded ones; and to their obvious advantage in fuller and more vigorous life; witness the amazing superiorities so manifest in the superlatively hot-blooded birds, not only over the ancestral reptilian stock, but also over the relatively much less hot-blooded mammals. Our own slight rises of temperature, as normally with activity, may be exaggerated, even to fever, and this to delirium and death, at a temperature still well below those normal to birds: yet how can we imagine a rise in normal temperature of our own species, or any other, save as a fevering, equilibrated anew to normal? And since rise of psychic activity is also associated with increased brain-circulation, with nervous and other waste, may we not see, even in their pathological exaggerations, something of the same interpretation—of instable advance? May not various types of insanity, even though rising at times to mania, despite their survival disadvantages, also include something of pioneering towards favourable variation? The high qualities of mind and spirit often associated with phthisis may here similarly be recalled. May not even the current eugenistic dread of taint from families which have presented any form of mental, cerebral, or nervous trouble, also be pushed too far? For without at all falling into Nordau's exaggeration, which almost identified genius with insanity, there have been many cases of such association. There are surely only too stable types, to which an infusion of cerebral variability might well be oftener of advantage, rather than the reverse. In short, the idea is not too lightly to be dismissed that potentially favourable variations may begin more or less pathologically, since disturbing to the general balance; yet that these may be, and sometimes are, equilibrated, and with advantage to the individual, in later life—and even offspring. In fact, this idea has come up from time to time since Sutton's notable initiative and we were not a little surprised to find something of this conception reappearing even in a recent volume on Cancer. As naturalists without pathological and medical experience, we are not qualified to pronounce in such matters, yet we cannot but see rationality in the idea, that some forms at least of pathological variation may be instable new variations capable of equilibration, and to vital advantage of the individual; or even with adjustment in progeny?

SOME BIOLOGICAL VIEWS ON EDUCATION

More than other men of science, except psychologists, biologists may reasonably make a strong claim to be heard in regard to education. For they are students of development, and education is the guidance of development. Biologists are concerned with the

trajectory of the individual life—youth, growth, the play-period, the learning-period, adolescence, and so on; and they are more accustomed than most men to think of the organism as one—Body-Mind and Mind-Body at once. Moreover, biology is the central descriptive science, based on chemistry and physics, leading on to psychology and sociology, thus affording a unique vantage-ground from which to envisage education. Thirdly, there is reason to believe—though few yet believe it—that discipline in biology is the least dispensable part of education, at any rate when we are thinking of education as a means of instruction and of preparation for life. For such reasons the biologists' views on education must increasingly claim relevancy, indeed even greater than those of any other scientific teachers and investigators, except the psychologists; and we seek to take them along with us.

Considered biologically, education is the control of nurture, so as to induce the best possible development of the hereditary nature. Here we mean by "best" that which makes most definitely for the kind of life that is a lasting satisfaction in itself. Or again, education is the endeavour to shorten the individual's recapitulation of racial evolution; and this includes the endeavour to help the individual to utilise—and even in his turn extend—the extra-organismal social heritage. We mean by the social heritage all that is registered in language and literature, in crafts and arts, in the mastery of nature, in the collective memory as stored knowledge, and above all, in the social life at its best, which we can alone truly call civilisation. This social *heritage* is for man as supreme as the natural and germinal *inheritance* is fundamental; yet education fails of its high ambition if the mind remains without freedom, bound by the trammels of the past. For the social heritage is not all to the good, any more than is the lien of the past in the individual inheritance. In either case, the legacy has something of burden as well as of wealth, of inhibition or worse, as well as of inspiration and impulse turned towards evolution.

Many a higher animal, as notably the otter, educates its offspring carefully, quickening their attainment of efficiency in their every-day business of life, and strengthening towards intelligence their behaviour in their environment, which now also includes man. This animal education is of great survival value; but it is very limited. It obviously differs from man's in being strictly parental, mostly maternal; in there being in most cases only an adumbration of the social heritage; and in the relative subordination of the inner or mental life. Distinct thoughts apart from feelings can form but a slender rill in the otter, clever and highstrung as it is; but in man, as they get fuller play, they form a broad stream, often insurgent.

Much needless controversy would be avoided by distinguishing between the utilitarian, the gymnastic, and the nutritive aspects of

education, though these doubtless shade into one another. Nowadays the three R's are viewed as primarily utilitarian; mathematics is our finest of mental gymnastics; history is a supreme diet. Reading, writing, and arithmetic, biologically regarded, are keys now necessary for getting at the racial heritage, tools needed in the bag of every respectable citizen. It will be granted that they may rise into art, as writing into drawing, reading into pageant and play. But beyond and before these, childhood needs the active, free, and full education of the senses, the play-exercise of the bodily powers. With these, too, is needed the fuller education of the hand—most vital and educative of organs, and with this that recapitulation of occupations in which children so delight, and instinctively turn to play. Yet this is truly utilitarian also. Thus the young otter learns to catch trout.

A second aspect of education from the fully biological (bio-psychological) point of view is to supply not only bodily but mental gymnastics, as did the Greeks of old. Here the aim is above all brain-stretching; and the particular method employed has to depend on the teacher's own stretch. Each method leads to some precision, some fineness of edge, some intellectual resoluteness, and some emancipation from what may be called the tyranny of the ancestral minds that lurk within us and keep us so often from having minds of our own. Even arithmetic, and far further, mathematics, are good brain-stretchers; but, this cannot as yet always be said of either natural or civil history. Many a teacher has done best with Latin prose; yet surely still better with Greek poetry and drama, while even the philosopher—witness Socrates—has a word for the child, though the Book of Proverbs has more. Some teachers tell us that is best which the pupils dislike most; but the element of truth in this needs many grains of salt withal. Yet why only this or that discipline, too much taken alone?

This brings us to a further side of education—mental equipment; what is often called the furnishing of the mind; not with mere static information, but with idea-seeds, that—with richly formative soil and evocatory encouragement of sunshine—will develop roots, shoots, and leaves, even flowers and fruits. What kinds of living knowledge are most essential? Surely something of all; yet the sad answer is—those that are most conspicuously absent in most of our youth leaving school to-day.

This child organism we are so interested in setting forth on the voyage of life; it can learn much by the way; *vivendo discimus*. Yet how is it to be best equipped? On this point, as we know—many men, many minds—*quot homines, tot sententiæ*; yet to the biologist it seems clear that Nature and Civilisation afford the great aspects of life, essentials by which all our studies are organised, all our interests are concentrated. Uniting these, hence oftenest interesting

in the first place, surely a supreme subject is the history of our race. At the very least there should be a growing familiarity with the general idea of the Ascent of Man—a great subject too for play—and with the more obvious significance of the greatest events and changes in the historical evolution of mankind; even starting with any one the teacher feels of value, then to a score or so, and so on. But these should possess the mind dramatically, through school acting and tableau, on to pageant and celebration. Every momentous social change and phase should be associated with its personalities (when picturesque heroes, so much the better) and with something of its correlated treasures, of literature and art. Every school, in making its illumined history chart, will find that its most significant milestones are oftener books than battles, creations more than conquests, and discoveries often more than dynasties.

Along with some knowledge of the way in which even a few great men and great events and great ideas have counted in human history, there readily arises a growing awareness that many of the great waves—as from Egypt and Babylon, Athens, Jerusalem, and Rome—have reached this town, this parish, and left their marks there, their distant past living on in our midst. The very stones are whispering, sometimes loudly calling; hence there is much to be had from observation—regional and city survey—which the studious reading of world-history cannot give; and which helps this later. It is also plain that real (not merely regal) history will involve a correspondingly balanced amount of human geography, *alter oculus historiæ*.

The corollary in the pupils' minds will be the realisation—first dim, yet later incandescent—that history is always a-making; and that they themselves at any given hour are either swimmers or drifters in the stream. To which will be added the growing conviction, so powerful a stimulus to diligence, that if we are to understand the present better, we must learn more about the past; for that is mostly still in our present, and not far to seek. Ever so carefully, yet without flinching, there should also be some illustration of the fact that just as our bodies are walking museums of a hundred and more relics, so in the fabric of our mind there are ancient strands persisting and interweaving, strands of the animal mind, the savage mind, the ancient and the medieval mind, and later minds as well. Emancipation—free thinking in the true sense—comes in proportion to our understanding of the mind in the making, and our willingness to have it shaken up, sometimes even upset. There is little fear but that the best elements of the past will survive, indeed return all the more clearly.

No doubt there is good History in many schools, just as there is good Natural History in a few others; but these encouraging yet too occasional successes must not blind us to the sad fact, that in

regard to both History and Natural History, we are mainly missing not merely the bull's-eye, but the target. It is partly because too much of the material and the teaching is nonchalant and humdrum, partly because we are too ambitious, our quantitative reach exceeding our qualitative grasp, so that we lose the substance in the shadow. It is partly because we have not thought resolutely enough about our aim, and partly because the social fabric we are enmeshed in is too much for us. But is not this largely because we are lacking in imagination, and in courage?

A further essential is that school children should be interested in the world without, both animate and inanimate; that they should know their way about, even at first a little; that they should be able and willing to make short excursions—metaphorical and literal—by themselves, and that they should be accustomed to think in the open—and not, as too much at present, almost exclusively in the presence of print. They should have "Open Sesame" passes to open Nature's treasure-caves; and next keys, even difficult to turn, in the locks of her museum treasure-rooms. Their introduction to each science should make them familiar with a few good examples (their personal details included), showing how new knowledge has been gained, and how the search for clearness has brought new control over things and life. Of great importance it is that they should begin to become aware of the general meaning of a Law of Nature—a uniformity of sequence that can be trusted to, in which no wishes of man can produce a shadow of turning. There can be no doubt as to the value of vitally biological instruction, but our present plea widens into the more general one, that the mind of the school-child should be fed with the facts of science, especially in regard to those large aspects of the outer world, into which he is going, and may spend the best of his life. At present we too often enforce premature analysis, and so effect little. What is worse, we succeed in killing interest, not to speak of joyous wonder. And education that does not develop the emotional life is anti-biological, chilling, often all but paralysing the unity of our being.

Just as every school should make and even emblazon its often-changing historical chart, and this helped by some good pictures, like Medici Prints, so there should be an active outdoor gathering, from wood and quarry, cliff and shore; thus filling shelves, often-renewed, always available (yet not always exposed), with beautiful natural objects—shells, bits of rocks, fossils, minerals (often truly precious stones), even feathers, mosses, withered leaves, which all are treasures when found, and can turn into fairy gold anew. Children and students alike soon learn to make and rejoice on such "beauty-feasts", as they indeed call them. And in Kipling's early home city of Lahore, it is still good to see the simple country visitors coming to his father's museum, and hear them calling it "Adjib-

Ghar"—the Wonder-House! Here indeed was much of the early education of Kim.

A further essential, from the biologist's point of view, is a vivid knowledge of the elementary conditions of health and happiness; using both these words in a broad organismal sense, including the psychical just as much as the physiological. Much more is meant here than lessons in elementary physiology and psychology, though there must be some of these, always guarding most carefully against the danger of premature analysis and self-vivisection. One wishes rather to cultivate an enthusiasm for vigour, both of body and mind; an awareness of the needs and ways of guidance of life; a knowledge of the common-sense ways of avoiding disease, and gratuitous mistakes; some understanding of the cult of joy, and of the art of forgiving and forgetting; a delight in mental gymnastics and intellectual adventure, as well as of enduring bodily hardness; a letting in of sunlight to kill the microbes that lurk in the dark corners of our being; instruction, in short, in the Art of Life.

It may be said that our grandfathers and grandmothers got on excellently well without any applied physiology and psychology, so why should we burn our fingers? But it may be doubted if they *did* get on so well—or even live so long and healthily—as is often supposed. In any case, their attitude to sex, for instance, prolonged a taboo—perhaps the most far-reaching of taboos—which has done, and is still doing, incalculable harm; and which it is for education wisely to rectify.

Moreover, as regards health and happiness, man's education is and must be ever changing; for, as compared with animals, he is a restless experimenting creature, seeking out fresh environments and strange functions, always adventuring into the new. He is subject to constitutional, occupational, and environmental diseases, which are almost unknown in Wild Nature, but have now to be guarded against. He has few dependable instincts in the strict sense; he has rebelled against Nature's sifting without substituting for it anything adequately searching. And so we muddle on.

Our son asks us for "bread", and, at great cost to ourselves, we coerce him into accepting a non-nutritive stone—which varies in texture in different schools—as from "Wars of the Roses" or other "period" for dates in history, to "French departments" for geography. Is it true that all this is past? Our son asks us for a "fish" (which indicates Nature Study), and we press upon his attention the value of a serpent, like premature chemistry. He asks us for an egg (history, for instance), and we try his teeth on a scorpion—such as chopped-off joints, of grammar-rules, and stinging tail, of their "exceptions".

The biologist must press the importance of *biological* instruction in schools; and this not only because it is organically interesting to

most children, and provides delight for leisure hours, but because Animate Nature is not only beauty-feast, but offers a wonderful new Euclid for the speculative reason. Again biology leads on naturally to an informed enthusiasm for health, and even to "health-conscience" as regards the community. Above all, in our predominantly mechanical age and its "pecuniary culture", it is—literally—of life-and-death importance, to keep alive, in the mind of citizen and statesman alike, the ideas of growth, development, heredity, variation, evolution.

Our main thesis—in these times beginning to be submitted by biologists for criticism and application more than heretofore—involves that pupils leaving school should have gained a living feeling for human pre-history and history, and thus a knowledge of the steps of progress that have counted for most in civilisation. With this, of course, a personal ability to find their way about (not less, but even more than do Boy Scouts) in Nature, with its fundamental occupations, and thus with introduction to the Order of Nature; whence comes a tingling awareness of the possibilities opened to them of increasing control of bodily and mental life. In so far as these essentials are missed, or deficient, our system of education, in school and university, remains an endeavour whose success is far from corresponding to the pupils' industry and their teachers' good intentions.

Some say to us—You are knocking at open doors. History, Nature Study, and Hygiene are all being taught in schools: what more do you want? Now there was never more instruction than there is to-day; and it is compulsory. Never was education more instinct with good will; though at great periods it was more thrilled by brains. This is true, and yet wherever we turn, and whether upon ourselves or on our neighbours, we discover mis-instruction and lack of education. We find thick clouds of ignorance hiding the sun, sluggish and flabby mental processes, a lack of understanding of even the biggest things that are happening, a submission to all manner of conventional superstitions and outworn catchwords. With these, too, an unconsidering submission to suggestions from the Unconscious in its lower forms especially, and thus without developing its multitude of sleeping buds to leaves and flowers. And it is to be feared that the interest in brain-stretching problems is for the time dwindling, while too many have practically come to believe in the uselessness of the soul. But it is not too late to mend; and the forces that are for us are greater than those that be against us, since mechanism is for life, not life for mechanism.

Before we close let us try to anticipate other obvious criticisms. It is plain, however, that the best criticism is experiment; and the biologist's proposal of concentration on the essentials of life has hardly been tried—since early days at least. So he must ask fair trial.

He is asked—What of the indispensable three R's? Are they to be weakened for the sake of History in "Outline", or of Nature-lore in scrap-gatherings at excursions, or of Health, in your self-conscious juvenile valetudinarianism? The answer is: Let us teach nature-observation first; for then the visually more developed child has no more trouble with spelling; since the queerer the word the better remembered (say *Egypt, Sphinx, crocodile!*). Thus interest "explodes", as Montessori says, into reading, often voracious. Keep notes of interest; that is, writing. Use arithmetic in nature and life too; thus all three R's are provided, and at their best. Our method, however, also—and even mainly—aims at the three H's—Hearty interest and sympathy, Hands busy, and skilful; thus from earliest flint-age onwards, it is that man's Head has grown clear, his hands have made him wise. With these three H's assured, by all means some (short-period) drill in reading, writing, and arithmetic; and between (and largely as) the drillings, which should be exercises in concentration, let us indulge in reading aloud, telling stories, singing songs, drawing pictures, playing with Montessorian devices, making things, and enjoying Beauty-Feasts. Other things will be added unto us.

Yet again are we asked—But what in the way of mental discipline is afforded by your impressionist history, your sciolism of everyday experience, your "How to be healthy and happy" lessons? The answer is that no one proposed to dispense with mental gymnastics, but we began our discussion by distinguishing between the nutrition of the mind and its stretching. Our essentials so far have mainly to do with the instruction; though our science, and all its companions, too, are ready to offer all manner of mental gymnastics.

After all the criticisms that may and must be brought forward against such proposals of vital change, we must alike face the facts. We see millions of young people leaving school and thousands leaving college without any grip of the history of their race, without live knowledge of the world in which they are going to live, and without even an elementary realisation of the laws of health and happiness. To the biologist these appear to be radical defects in education. They were not tolerated in tribal days, nor even old rural ones—nor can they be much longer. In wellnigh all the worst schools we have known, there was some good teacher struggling with adversity; and happily now there are not a few schools in which the better are in majority, and with fresh and free progress in many directions. What we plead for, they are often doing. We seek but to help them, to strengthen their case, as truly progressive, because Life-advancing, Life-enhancing.

EDUCATION FOR LIFE AND HAPPINESS.—It is not a little strange, seeing that all education seeks and claims to be "a prepara-

tion for life", that educationalists—parents, teachers, and public authorities alike—should so commonly leave the study of Life out of account in their teaching. We know that mothers at home, and fathers after their work, alike think of education as for life, and still more the best teachers too; yet in the pressure of home or business cares, and the routine of school "subjects" and examinations, neither home nor school have yet found time to listen to our plea—for Life in education. Time was, when as naturalists we had great hopes from our nature excursions and demonstrations and lectures, and from making a school museum or garden here and there; and yet more when we were helping to get "Nature Study" into the Education Codes. But though we still thus do what we can, we have come to see that a far larger, and even thorough, change is needed, and throughout the whole world of education. For here, with all respect to the advance of psychology, and gratitude to our many masters—whether for help to us as teachers, like William James and Stanley Hall, or for deep-sighted contributions like those of Freud and Jung and Adler—we yet submit, and to parents and teachers as well as readers, the simplest and broadest generalisation of our own observation and experience, alike as teachers and in life, that the many (alas, proportionately not so very many) conspicuously happy and healthy, productive and effective, men and women whom we have met in life, and these at all levels, from simplest labour to highest achievements, and with or without fame accordingly, are those who have enjoyed a happy (even more than always healthy) childhood. Motherly instinct, of course, expresses this; paterfamilias gets it too; yet either or both may spoil the child; indeed only too often do so: and school, with all its good intentions, too much falls short as well. Beyond home instinct and good intentions, beyond school and code routines also, we need knowledge and guidance, and this with foresight, towards all that can fitly prepare for life. Towards this we have had a multitude of counsellors, and from old times to this day, and often with wisdom. So of all this, what briefer summary than the old Indian story—in which the boy, awaking to the urges and perplexities of every opening adolescence, asks its fundamental question, "Shall I go with those who seek pleasure, or those who follow virtue?" and gets the answer, "My son, while men are seeking and disputing, here for virtue, or there for pleasure, do thou possess thyself of the realities of both!"

QUALITY OF LIFE.—Though we cannot name any precise debt of new biological thought to Froebel, evolutionists have much to learn from his vital applications in education, for his characteristic idea and aim were in spirit truly biological; those of the full development of the child's mind and its culture, like that from seed to shoot and bud, and thence to flower and fruit. Hence his endeavour to give full and free play to the child's own life; and instead of crush-

ing its young growth beneath too massively applied manure-loads of conventional instruction, to encourage it to strike its own roots, deeper and deeper, albeit into a soil enriched by the accumulations of the past, and there freely making its own vital selection of these. We increasingly see that only in such way can the idiosyncrasies of each individual be fully respected and developed into the personal—it may be the unique—contribution to the work or culture of the world which it is, or should be, his life's ambition to make. Hence the developmental educator has long been striving to mitigate the tasks imposed by social authority, be this of church, state, or social convention. Thus, too, he is shifting the educational problem from memory-acquisition of these programmes, and within fixed times for examination tests, to the pupil's more leisured—and yet swifter and surer—utilisation of such vital elements as these possess, and in such measure as he may be capable of. Hence any biologist, when free enough from his specialised interests to consider the education of his own children or others, may well begin to make experiments of his own with them; and such endeavours are of increasing influence, even on the official school and its authorities. In field and garden, the good crop depends on the one hand on good seed, on the other on good nurture, in good soil and with good season: and what is this good season, but a succession of good days?—a time of well-watered roots, but also of well-sunned hours. All this is manifest in normal infancy; why not also more generally in childhood, and in adolescence, indeed even in maturity? Was not this the element of vital truth in Rousseau's letting Emile run free till twelve years old?—and as Darwin practically did far longer? To assure good days—no doubt in fuller ways than either enjoyed—is not that the best of methods for education, and even towards its highest?

So why not this higher functioning—both active and passive; and all throughout good days, and towards better and better ones? Let each day absorb its wealth of impressions, and through all the senses; thus real education—visual, auditive, tactile, and more. Motor activities are, of course, needed to match; and all may be associated with deepening and strengthening emotional life; as to and through song and dance, to drama.

Education thus becomes truly practical; with throughout occupational activities. These are indeed fundamental, for the individual as for the race; and with each there readily comes large acquisition of its social tradition of culture; so that even its scientific and literary presentments, on which official educators so primarily insist, are acquired, at first more gradually, and then more readily. Experience shows that boy-prentice-students are soon able to do as full justice to this as can be wished; and still better in adolescence; so that efficient maturity comes far earlier than

to the conventionally educated, even in their best conditions and endeavours so far.

Amongst savages early education is of the senses, of course practically trained, not formally taught; such training is by example and imitation rather than by precept. No amusements of childhood are more attractive to them than are the precocious imitations of the activities of their elders; so that the practical and economic life is thus arising through play, before it becomes a necessity. It is as adolescence is reached, that full and definite training in traditional lore and custom is imparted; it seems to boys more than to girls, though of course to these more than anthropologists can easily observe. In fact, we may almost speak of home apprenticeship in childhood, and of this early education as followed by something corresponding to our academic stage.

Instead of the teacher, as in most countries, on duty in the classroom for a long succession of hours—a number beyond the experience and powers of university teachers and thinkers, who can teach but a small number of hours at most, and practically that of the long business day—is not he the best teacher who is actively cerebrating with his pupils every morning, and then playing and working with them in the afternoon? Hence the English school preference for the picked athlete, the "Blue", as schoolmaster; though the grave deficiencies of his customary education need to be supplemented; and these in at least two ways, by fuller environment of Nature and by active occupational and even artistic activity. "The Play-Way" is here a good example of this line of progress.

If so, may not our needs of secondary and technical education—as of choice of occupation, and preparation for it, of sound and steady attainment of one's efficient place in the social whole, and of fuller and fuller inheritance of its scientific, literary, esthetic, moral, and social culture—be increasingly met; and this centrally through the recapitulation of the fundamental occupations, with their respective cultural developments?

LIFE-METHODS IN EDUCATION VERSUS POST-MORTEMS —The so often poor results of educational endeavour—patent as these have been and more and more are—are too commonly blamed by parent on child, by teacher on boy and girl, and by professor on student; as often conversely, by pupil on instructor; while, too often also, all parties more or less come to the feeling that the given subject—and so more or less every subject—is "difficult"—and even "dry". But all these views are essentially nonsense; for every subject, whenever presented as living, is full of interest and that ever-growing. Thus geometry has been fascinating to all its initiates, from earliest Pythagoreans to subtlest post-Einsteinians. The like too from astrologer to astronomer, alchemist to chemist; and the

intoxicating ecstasy of Archimedes one has seen renewed in a physicist discoverer still fertile to-day. Nor need there even be discovery: the landscapes and the simple details of life by turns were thus ever rousing Haeckel into outbursts of eloquent appreciation as we rambled the Jena hillsides with him; and every field-naturalist worth the name has felt the like, and from moments of childhood to old age.

The fault thus lies essentially in method, say rather in mode of presentation—far too long, as a rule; and even nowadays too commonly the "rule" comes first, the examples and exceptions later; so the life, that makes literature as well as science, is thus reached only by the few in whom it is too strong to be thus killed. All this especially since the decline of Hellenic culture into Hellenistic, so with Roman slave-pedagogue as its outcome; and the like too since—and with—the decline of the Renaissance, which it at once expressed and advanced, in vicious circles even to recent and even too many contemporary ones. In fact, above all since the fear and disgrace of failing in examinations came in to replace mere physical punishment; and so to drive sensitive young spirits towards nervous exhaustion or breakdown—and indeed in Germany before the War too often even to suicide; and far oftener condemning girls towards that comparative sterility which is so lamentably inflicted among the women thus "educated" in so many countries to this day. For in the great days of "the New Learning", the new geography and astronomy also, all these ideas were aflame, each full of fire and light; and even when grammar was being worked out, we see its glow and gleam irradiating "The Grammarian's Funeral"; though that scene is also Browning's most significantly chosen of historic symbols. For as the supply of fresh fuel to freshen these fires of thought abated, the scholars came to pick up trifles, to scrape among embers; since which school-ushers and pupils have too much gone on sitting around the ashes of all these; so in the cold and dark.

Passing from this imagery to the conditions it expresses, what better example than those too long afforded by the teaching of the biological sciences? That "dryness of botany", which still too much repels children and women who love flowers, and even gardeners who tend them, is soon dispelled by the botanist whose love and tending have kept him child, woman and gardener in one, albeit encyclopedist too; and when he teaches in that order, with feeling, interest and experience, they cannot but soon desire more of his knowledge too. Yet botany is still mainly associated in the popular mind with our Latin names of species and these without understanding of their international code-value; and beyond this their nature-wide order and its significance.

Yet when we teach botany in fields and garden, and interest our

audience—be it young or grown matters little—we soon find them willing and often eager; for they soon see how we must keep clear notes and names of what flowers, which insects, are involved in these varied and fascinating interactions, in their real life, and towards life anew. See how London citizens, as well as country visitors, crowd in thousands to Kew Gardens and to the Zoo, since there all is living; yet in the great Natural History Museum—albeit so incomparably richer and more orderly for science—they are easy to count, especially in the long galleries beyond the Central Hall so vividly and "popularly" (i.e. vitally and evolutionally) arranged so that all may see; while the great Herbarium upstairs, and again that outside Kew Gates—though each a *hortus siccus*, a concentrated World-Garden—is only for consultation by the specialist inquirer.

Again, youths often take to medicine with real interest; yet only one in a hundred of these yet comes to anatomy for its own sake, though Huxley was far from being the only teacher who could make dry bones live. But when one makes up his mind for medicine, common sense shows him he must learn anatomy, and for surgery more still; yet it is again but a minute percentage even of these good students who become initiated far enough to feel the enthralling interest which makes anatomy professors, and again from among these the fully comparative anatomist. Only when this stage is being reached, and that of the comparative physiologist as well, can such a museum as the Hunterian, in the Royal College of Surgeons, with its wealth of significances and suggestions, be adequately appreciated—while the public who may stray in, see mainly the giant's skeleton as a curiosity, and the megalocephalic dwarf's as a horror; since these at least each give them its realisation of the formidable possibilities of life.

Life: that is the magic word which revives all dry bones, and these throughout all studies: and hence as schools and universities return to Life—and this in evolution—as they are indeed doing, albeit still too partially and too slowly—their vitalised interest and effectiveness will soon rise into a Revivance, and this veritably evolutionary, compared with which even the glories of the Renaissance were but of early and soon clouded dawn.

Here then is the secret of education, biological and general alike. Ordinary human and social life are, and can but be, essentially interested in the living, far beyond all due conservation of memorials of the dead, as in cemetery or library, in museum of relics or even portrait-gallery. Yet when all these are reunited into more lifelike presentment, be it but as in Madame Tussaud's waxworks, the public go in their crowds again; yet most of all to the play or pageant, since there even antiquity seems really in life.

Thus too it was that the world's unquestionably foremost teacher

of biology—Darwin—educated himself; and this from instinctive truant-roamer to eagerly observant and intelligent voyager, before returning with steady patience to the many and fruitful inquiries of his later life, which only then could face a spell of real museum work as with his barnacles, and in laboratory with his insectivorous and moving plants, though finding gardens and fields, stockyards and dove-cotes even more interesting and more productive too. As he matured, he felt more and more the interest of learning much of what he had avoided (and as results showed, rightly) as a student and solitary searcher, since now seeing its frequent values for his at once eager and patient questionings; yet always as a naturalist, generalising as well as specialising on Life.

In summary then—Life first; and its analyses thereafter. The vast and complex Life-Drama of Organic Nature in Evolution—and in which we ourselves are no mere spectators, but also actors, and throughout our lives—is full of interest in every phase of act, every scene of season, and with its innumerable players; with their fewer salient type-protagonists and leaders, their laggards too; and each and all increasingly seen as interacting, with all their developments of characters, towards comedic success, albeit with many an instance of tragic close. Is not all this at once Man's history, past, present, and possible, and that of Organic Life-forms as well?—and so the essential spectacle for sociologist and for biologist alike? Keeping to the latter's terms, here is Ecology and in Evolution; here too we are making out the processes of individual life in Physiology, and even rationalising its Development; so with Phylogeny and Ontogeny intereacting together. As we watch this Life-Drama, we note its forms as species and arrange these, in our list of Dramatis Personæ, as our Taxonomy; we scrutinise them in Anatomy, and compare them in Morphology. We look into their general past, and even into their individual up-growing, as Palæontography and as Embryography. Thus we are at once grasping the essentials of each of our eight sub-sciences of Biology and utilising these; so also with the like eight social sub-sciences, as in our previous graph summary and comparison of all these.

While occupied with each of these specialised tasks, we can hardly but for the moment lose full consciousness of the others, and yet more of the vast drama ever upon the stage; yet with help of all these, we can ever return to watch it more fully, since now with bettering understanding, deepening appreciation.

EDUCATION BIOLOGIC VERSUS MECHANISTIC.—After all is said against post-mortem education, must not we scientific men largely blame ourselves? If our problems, and their applications also, are not realised, is it not because the specialist, after all, is too much but an individualist among others? Let us systematise our

problems, science by science, and state all we can see of possible applications too, so utilising not only our professional and technical groups, but combining these. We should thus have something of a policy to put before the intelligent public, and thus with growing support, from individual and public, municipal, national, and by and by even international as well. We have already beginnings for all this, as in scientific and professional societies and in the British Association and the British Guild of Science, which intelligent statesmen have recognised, though as yet but personally. In every University city, indeed in every county and town, with its scientific and other societies, often open-minded and active, we should thus have a veritable policy, of surveying towards service. With such activation of thought, such vision of applications, the present separation of "theory" and "practice" would pass into a co-operation of ideas and of aims, in which the scientist and the practical man would rapidly and encouragingly escape from their too common mutual isolation, and work together. Of this there is already no lack of illustrations and from each side. Witness Kelvin and Edison, for physical science and its applications, and the like no less between biologists and physicians, as from Pasteur and his Institute to Sir Ronald Ross and the other cleansers of Panama which at length made its canal possible. And so on, as for psychologists and educators, each at best when helping the other.

But why then is this comprehensive presentment of knowledge so delayed? For two main reasons. First that notwithstanding all that Darwin and his successors stand for in science, or Pasteur and his successors in applications, our industrial age has so concentrated upon its mechanistic progress, that its public still fail to recognise that it is as yet the mechanical and the pecuniary culture which dominate thought and impel action, and not yet the vital and evolutionary comprehension of living nature, and of our own lives above all.

Yet Biology is becoming more appreciated, as its medical and even economic triumphs become increasingly realised. We are also plainly in an age of corresponding progress in psychology, and of its educational applications—witness how Freud and Montessori are now of world-wide fame, and—what pleases them better—influence. With the bio-psychological viewpoint affirming itself, as of life and for life, it casts new light upon the physical sciences. It even claims to reinterpret these; and, what is not a little encouraging, with living physicists and mathematicians to help them—witness Whitehead's projection of the organismal conception into the electronic theory of the atom, or Eddington's virtual renewal of Berkeley's acute psychological criticism of what everyday observation and practice alike call "matter". Here, in short, is a turning of the tables upon that so far legitimate (yet we now see exag-

gerated) "materialism", as from say Büchner to Loeb, for which living beings, in their organic and even psychic functionings, were but a dance of material and energic change, and thus, and thus only, to be interpreted. But even with this advance, can a scientific policy be elaborated? It is no doubt much thus clearly to see that "there is no wealth but life"; and that our essential "progress" must thus be in "life more abundantly"—Life in its Evolution. Thus as all must agree, our mechanistic progress has to be judged. What use of microscope and telescope, albeit marvels of mechanistic construction, save as added eye-power to us, what value of railway and speed-ship, motor and aeroplane, save for enhancement of our locomotion, or of telephone and wireless, cinema and what not, save as extensions of our natural and organic psychic powers? At first sight this is a commonplace; for every mechanical inventor has seen it, indeed, as his main goal, and often his only reward. Yet has not the industrial age, in using these advances, also deeply vulgarised them; as for "business" ("not for our health!") and for finance, so widely misused and debased—and above all for war, increasingly destructive—war, with farther destructive armaments, now wellnigh capable of destroying humanity and organic life together.

This present outrunning of the sciences of life, by the mathematico-physical and chemical sciences, has been the essential and dominant character of the Industrial Age throughout its progress, now ever attaining new culminations. Yet it is no small sign of hope that its serious thinkers begin to realise this. Witness, and as a date in contemporary history and its interpretation, the recent Centenary celebration of the Institute of Engineers, with the admirable retrospective address reviewing "A Century of Progress", in which their profession has been the very foremost, and by their fitting and well-chosen President, Principal Sir Alfred Ewing, of Edinburgh University, than whom probably no engineer in any country has had more varied experience, in science and invention, in war and peace, and in education, from Navy-School to those of all the professions. Yet his address ends with realisation of what is nothing short of world-tragedy, and this both past and anew impending. We look through the address for some sign of hope, and so there is—a call—indeed a cry—for some renewal of social and moral progress to save us ere we perish and by each other's hands, super-mechanised and super-armed as these are more and more becoming. But here—albeit Principal of a University which has justly been earning its eminence through ages past, in the arts and sciences of peace, incomparably more than in those of war—Sir Alfred gave his hearers but faint light, and no definite leading. How so? Because of the essential nature of the Industrial Age to which engineers belong, which they so largely create, and also maintain,

with its corresponding limitations. To explain and define this Industrial Age we need an excursion into the past for its earliest analogies. Amid the contemporary discoveries of non-industrial character and application, and hence little valued by the industrial and pecuniary culture, save as side interests at best, what have been greater than those of man's history—and of his pre-history? This early period, at first called the Stone Age from its surviving flints, was next seen to need discrimination into two main periods, the earlier and later, and each of course with its sub-periods and peoples as well. The Old Stone Age, thus called the Palæolithic, with its chipped flints increasingly varied and well wrought, was thus succeeded by the Neolithic Age, recognised primarily by its often polished implements. But these differences were next seen to throw light upon two fundamentally distinct civilisations, the earlier of hunting type, the later predominantly agricultural; and with their clearly different relations to organic life accordingly, the former necessarily finding its success in the successful infliction of death; and so expressing and idealising this in art, and even deepening to beginnings of religion centred around the tomb. Whereas the later civilisation centred upon the increasing promotion of life; and through its long continued progress there have come down all our cultivated plants, and all our domesticated animals—say, indeed, the plants which have so much cultivated man's powers, the animals too which have so much domesticated them. What saying of our time is more hackneyed than that "war is fundamental in human nature!" That this is a crude libel on feminine nature needs no argument; and but a moment's thought is needed to see this inherent in occupational nature, that of the hunter, who can only too readily come to man-hunting, and who thence develops war, by mobilising, impressing the other occupations into his service, and this increasingly, as the history of war so much shows, and now its menacing future, since wellnigh completion to perfection of destructiveness.

In summary, then, the pre-historic past shows clearly two contrasted civilisations, the Palæotechnic and the Neotechnic, the hunting and the agricultural, and the significance of this contrast is its obvious and clarifying application to our Industrial and Technic Age, as also presenting two periods, which its economists should long ago have distinguished, and as essentially Palæotechnic and Neotechnic. The former is still the dominant one, since characterised by the reckless and wasteful exploitation of natural resources, whether mineral and organic, towards mechanistic industries; and maintaining and increasing population for its service, and thus irrespective of their evolutionary life-interests; and all this essentially in terms and tokens of the corresponding pecuniary culture, as its dominant technique and even obsession. The latter phase of

the Industrial Age, now and increasingly in progress, more and more recognises the necessity of the conservation of actual resources, and of the increasingly scientific and skilled application of these, towards not only the needs of life-maintenance, but of its increased efficiency; first, no doubt, for industrial purposes, yet also in growing measure towards health, and this even in its organic and mental progress, as through public hygiene and advancing education. It will thus be noted that, as the neolithic civilisation was essentially agricultural, and with higher social type accordingly, so also is advancing our industrially neotechnic age towards Biotechnic action.

It is easy to see that militaristic, nationalistic, and political developments have ever owed their dominance and advance to their equipment of arms by mechanical industry. To this they have ever owed their force, from the time of flint-axe and arrow-point, through those of the sword of bronze, iron, or steel, to the missiles of our day; whence wars and nationalisms, empires and conquests, and even support of internal order as well. But as we admit this, we next see that when and where society thus centres its organisation and its activities upon mechanism, rather than life, and on coercing this by force and fear rather than advancing its evolution by help and hope, there, in such society as to-day's—and despite all palliatives and means of delay not to be despised, such as Hague Court, League of Nations, Kellogg Pact, etc.—there Death is ultimately arbiter and master. Does this seem discouraging? Not really so, to the biologist. He sees that such peace-efforts are but of war-peace, with war latent still, are too simply mechanistic, at best but brakes upon the Avernian descent, good for but so long as they can hold. What then is for him the turning-point? That of dominating anew the mathematico-physical sciences, and so with these their mechanical and pecuniary culture, to and by those of Life and its service. Yet this not simply in quantity, or in mechanical powers, for the paleotects have done that, not even in industrial efficiency, for the neotects are doing it; but in vital progress, in and of life and the knowledge of it together, since it is by living that we best learn—*vivendo discimus*.

Progress towards what goal? The Super-Man? Yes, in a way; but not that of Nietzsche and his like, with their often brilliant expression of what is none the less biological blundering. For, after all is said that can be for the mastery of the masterful, and in contempt of the submissiveness of mere slave-morality as but feminine weakness at its worst, there remains—and as the supreme fact of biological science, and its discernment of the evolution-process—the normal overpowering of the self-regarding life, by the species-regarding, the sex-regarding, the offspring-regarding, the group- and kind-regarding. And with this the manifest proof that it is in this other-

regarding phase, and its ever-widening applications, that the higher development of the individual is realised, and with it that of the species. It is but a misunderstanding—be it of free-thinker or of Protestant, be it of scientist, of mechanist or mammonist—to think of the Madonna with her child as an outworn symbol. So far from that, the biologist has known, since Linnæus, if not earlier, and has ever been learning more fully from life-forms, extinct and living, that the evolution of birds from reptiles, and that of mammals too, was by no means one of mere tooth and claw, but by reason of their profoundest evolutionary advance, that of mothering. It is in terms of this progress, beyond all others, that Mammals are and have to be classified, as from the egg-laying and all but bosomless duck-bills to marsupials, and thence again, through more and more effectively mothering types, to our own, so much the most mothering of all. The "Matriarchate" of certain anthropologists was no doubt in some respects exaggerated; but none the less there was and is much in it, as existing peoples still show. And now, with that increasing liberation of womanhood from ages of over-patriarchate pushed to injustice, obscurantism, and oppression, a better age—since increasingly biotechnic and bio-psychologic, is fairly beginning. Hence it is for us as biologists to understand this ancient and symbolic cult anew, from the rude mother-images of pre-history, and through Magna Mater, to Madonna. Ignorantly though such may have been worshipped, there is only the more need for the recovery of their scientific and evolutionary significance. Nor is this merely a task for biologists: the ancient priority of historic religion is being recovered; witness Cardinal Lavigerie, the missionary Church-Prince of French Northern Africa, not only sending out his priests to robe and ride like the Arabs they went to preach to, and forbidding to them the church-adornments of Europe, but telling them that the Madonna for their preaching-tent must be painted afresh from an Arab mother and child; and that when they went further south among the negroes, she must be a negress too, and with her swarthy child. Here in principle is Comte's "Humanity", and "Santa Sophia" as well: so as biologists we can thus but acknowledge all these teachings, otherwise contrasted as they were, as essentially those of initiates of bio-psychology and evolution; and before either technically equipped biologists or psychologists had got so far. It is a mere survival of crude "fundamentalism" on one hand, and of no less crude "rationalism" on the other, to doubt this incipient and renewing harmony of science and religion. For here the highest scientific truth of the evolution-process, and its idealistic and artistic expression by religion, are essentially and definitely at one.

And as to practical policy in education, it is no real ground for alarm that the teaching profession is so largely becoming a sister-

hood; the more since this is also becoming reinforced and inspired by motherhood as well. There is no fear that such truly evolutionary educationalists will fail to call in and utilise us men for all we are worth, as from craftsmen to artists, specialists to philosophers.

BIOLOGICAL EDUCATION.—Every scientific worker owes much to his training, and this in fellowship amid social groupings, as from his first amateur naturalists' society to laboratories, zoological stations and what not; and also to his periods of travel, with changes of social atmosphere and climate of ideas, as well as fresh opportunities of nature-observation. Thus though Darwin does not mention it, and possibly hardly noticed it, his discipline beyond the rambling and impulsive truancy of boyhood and adolescence to that steady industry up to the limit of his strength and powers which so notably characterised his later life, must have owed something to the regular navy discipline of the *Beagle*, and his *Naturalist's Voyage* to its regularly kept log. Indeed must not Captain Fitzroy—himself a close observer and judge of men, a wise disciplinarian and also a widely ranging scientific thinker, and later eminent among meteorologists—have been of important influence on Darwin's life, since combining more authority than that of his parents, with more regular educative vigilance than that of his professors.

Educationalists are awakening more and more widely; and education begins to find its way back to life, and thus comes to life; so we begin to see that we have to reorganise educative conditions more fully all round, thus ourselves learning from all manner of educative groupings, past as well as present, towards uniting their best qualities as far as may be. We realise our present results as disappointing; but too readily blame our pupils for this. But when we do not catch our fish, we know there is no use blaming them; it is for us to amend our methods. Beyond the advances of physical science in the disclosure of nature's potentialities and powers—even to radium itself, though as yet less realised—are those of pure and applied psychology; as is evidenced in many ways; as notably from Stanley Hall's *Adolescence* and *Youth*, to the growing literature of industrial efficiency. Beyond all the amendments, happily now often appearing, of the drudgery, desultoriness and trivialism too largely mingled in current education, that critical reviewing of past and present methods which is already part of a teacher's training has to be extended, synthetised, and experimentally applied; and this to novitiate, initiation, and adeptship in life for each of its growing phases, and so towards its maturity of flower and fruit. "Genius" has too long been but a mythic word: it is the blossoming of powers elemental in man even from his earliest evolution, and thus is so far latent in all men. "Culture", too, is still too much in the abstract, and from leisured retrospects of past growths and flowerings; it

knows much of "the best that has been thought and done in the world", but is too easily content without in turn doing the like. But culture has also to be more literally understood, more realistically applied, in its full sense; that is, of steady activity, towards aiding growth to its fullness, flower to its beauty, fruit to its perfection. The botanist values his herbarium, and uses it with due scholarship; yet he rightly understands it as *hortus siccus*: and so he tills and tends his botanic garden into the very cynosure of his city; while in the yet more skilful cultures of the florist, he and his flowers go on surpassing themselves year by year.

Such experimental cultures avoid too current limitations, as of those who insist too exclusively on nature or on nurture, on character or on environment, by combining their respective half-truths, and making the best of both; day by day, season by season, year by year. Thus while the florist and the cerealist, as the super-eugenists they are, are ever giving us improved seeds, there is no more impressive lesson towards their right treatment than that of growing a row of seeds of such good stock in "culture-solutions", of which only one has all the necessary soil elements, and all others are deficient, yet each only in some one essential. For thus all our seedlings—save that of complete soil-environment, and consequent normal development—soon show pathological states, and these quite characteristic for each deficiency. Similarly too for the experimental supply, or limitation, of other needed conditions of environment, as of light or temperature, water or air. In such ways are preparing great contributions from organic culture-processes to those of human life; and these can far more readily be applied in schools than as yet in village, town, or city, awakenings though these also begin to show. So if our culture of Nature's children be thus already attaining such associated perfection as in our best gardens, and with individual developments surpassing previous records, what may not be the culture of the childhood and youth of humanity at their best, and as guided into more complete and appropriate conditions and utilisations of environment; with appreciatively sympathetic and skilled discernment and evolution of their own latencies and potentialities, and thus to higher levels than our own. In this progressive perfecting of education, with its vast and varied collaboration of educationists and their culture-resources—at present strongest upon the humanistic side, or sometimes in the mathematico-physical sciences—we make no criticism of exclusion, but plead for yet wider inclusiveness. Hence in this must be urged claims as yet far too little satisfied—those of Nature-studies and Nature-activities, as fundamentally educative in and from childhood, and as preparatory to fuller knowledge of life in later years. For thus education becomes more living, more truly developmental and evolutionary. Indeed is it not for lack of this

direct contact with life and inspiration from it, that the living spirit of humanism has so often fallen to the dead letter, and the appreciation of science been so much arrested at the mechanistic level?

OCCUPATIONAL EDUCATION.--We have ventured to speak thus strongly, and at such length, on education biologically and humanly considered, not only from our long life as teachers, but on various other grounds. Thus notably by watching the rapid growth of the Boy Scout Organisation, which was lately celebrating (1929) its coming of age, and increase towards a third million of membership; and, what is far more important, its remarkable development from an at first too militaristic spirit to one of peace-making internationalism; and with more and more of real and vital education, as in open-air geography and nature-study, in occupational experience, and in social service. We note too the rise and growth of kindred groups, as yet smaller, but each in its own way making its kindred contribution to educational progress, e.g. Girl Guides, Seton Indians, Woodcraft Chivalry, Kibbo Kift, etc. As naturalists we have also in our own environments been able to encourage our own boys and girls and a few others to such pursuits, thus supplementing (indeed, in several cases largely superseding) their conventional schooling, and advancing their college studies; and we are thus experimentally encouraged by the immediate life-facts, that these young folk have each and all grown up into effectiveness, in natural science or its professional applications.

Leaving them to express themselves in their own careers, we may briefly summarise the education—largely the self-education—of the one lost to us in the war. From childhood home of widest outlook over one of the most picturesque of cities and its landscapes from snows to sea, and with summers in kindred ones, and thus more of real (and less of book) geography than usual, he early grasped the there manifest conception of the Valley-Region, small or great, as the essential unit for wider world-knowledge; and this to be acquired by widening out of excursions, and by and by in further travel. Next came interest in the varied work going on at different levels; so in time not only from sea up to snows and back again, but to an ever-keener admiration of its workers—"men who can do things"—whence ambitions alike to learn to work with them, and to know them better. Thus, with little experience of schools (save for most of a year at our village school, and one at a famous one, so avoiding isolation in either social class)—his youth was essentially characterised by the happiest variety of occupations; and thus from earliest helping of mother, in household or as errand boy, and helping father in the garden, to laboratory-boy and in each of our departments, of botany, with much in field and garden, and of zoology by the sea. He thus came to know fairly well not only the two fine valley-regions of Forth and Tay within his ordinary

experience, but more and more of others; and these with further occupational experiences—"real work", as he rightly called it. We knew, before the War proved it, that even in a few weeks, a keen apprentice gets to the fundamental notion of his trade, and even some way towards proficiency in it; so thus arose, from such occupational endeavours an encouragingly rapid and varied acquisition of skill. And even of relevant science with it; this also acquired mainly by observation and experience, and with books used more for reference than for regular reading. All this the more, since—as every youngster feels, and often now begins to know—it is more interesting to begin drawing one's own books, before reading through the mostly written ones of other people. With such initiation into visual art, and encouraged by an artist friend, the Art College came early to have its appeal and use; and so too, from musical impulse and environment together, came gradually expression and facility, ranging from folk-instrument, folk-song and dance, to their further developments in culture. So with further science; since an observant rambler comes to know the rocks and minerals of his region, its flora and fauna too; and all these from shore to hill-top ever offering new wonders; for which again books have their right place of reference. With this real nature-knowledge, it was but natural that after the university departments had been reached, their laboratory work, museum study, and continued excursions were later strengthened, clarified, and extended by reading, now more continuous, yet also rapid, and thus brief; and that the academic result was of the highest. Yet the occupations of the valley region had remained the central interest—with learning from its expert workers from boyhood—hunting with the camera-wielder instead of the gamekeeper, sharing in woodland and forestry work, sheep-tending with the shepherd, labouring with the crofter, ploughing with the farmer, caring for animals with both, and for the village and glen with its chieftain. In such ways came real grip and understanding of the main occupations of upland and plain, and these increasingly to skill; as with the botanic gardener, and then the even more skilled French-imported intensive one. And as the full developed peasant has ever been something of builder ("Bauer") as well, opportunities of learning under master-mason and joiner were eagerly utilised; and next came assistance to a town-planner. John Ruskin, than whom few have had wiser insight into nature and labour as educational, long ago insisted on the horse and on the boat, as factors for the education of manhood up to its highest powers—indeed, as very best among the resources of his projected "Trial School", here so far experimentally realised. So Ruskin's teaching was experimentally justified in life-long progress, as from the child's fall off his donkey, to the youth breaking in horses for the war; and at first, of course, learning by far heavier flings and falls. So, too, for the boat, from childhood onwards, and from river out to sea-fishing, up to the two severest sea-tests—that of steering the life-boat in its danger-drill, and that of Arctic exploration. But what of "regular" education? That, too, developed in living—as for Latin primarily from its use in ritual, with more of great music accordingly, up to Palestrina and thence to our day. Modern languages, too; on one side from the people and their

songs and ballads, for Scots, Gaelic, and Flemish, and on the other in educated homes, for English and French, with something of their literatures accordingly. So, too, for science. Geometry became solid through stone-hewing; and so on for geology, botany, and zoology alike, and for meteorology with observation of land and sea weather. One's public school and university friends were long dubious of all this: said they: "All very interesting and happy, but what is to become of your young folks when they have to go out into the hard world and its struggle for existence?" Said we: "Our anxieties are all for your young folks, at their great schools; for when they have forgotten their parsing and construing and have got tired of their kitten-ball-games (though ours, of course, can enjoy these too), what can they do—unless you can afford to protect them from the struggle for existence—save to begin again where ours are now? To be able to live by simple labour, efficiently and happily, as ours at present are ready to do, is already a life of active happiness; but next it is leading to the direction of labour, the work for a true governing class, which the too prevalent education strives to reach too much by way of verbalistic empaperment; and this too simply relieved by play." Yet in the first month after graduation a choice of ten unasked appointments—in botany, forestry, geography, town-planning, etc.—seven of these on levels usually kept for seniors farther beyond new graduates—was offered; and that affording further travel, leading to exploration, was taken. Then came the War—and in 1917 death in battle; yet with record as "best observer in the Army", and one of our two British "aces" of the air first singled out by our French allies for the Legion of Honour.

This record is outlined at such length in evidence of the proposition that it is on such naturalistic and occupational lines that we may readily have far more vital and efficient "educational reform" than government departments, or even the progressive schools, are yet as fully facing. It is in the movements towards recapitulation of real life, and these of widening range, ever heightening its developmental level—like the Boy Scouts, and kindred groups above-mentioned—as in cases like the above also, that the educationalist and the biologist may best combine; in co-operation with boys and youths themselves, and of course with girls too. It is also clearly to be noted that here was no case of "infant prodigy", or of anything like it later; on the contrary, here was just the "good average boy"; who could have been easily subdued to cram and exam, relieved by the usual games—or unrelieved, when lowered to compulsory; as is being done to tens of thousands more. The one psychologic element clearly marked from the outset was sympathy, far more than intellect; and as that was encouraged—instead of being dulled by pseudo-intellectual schooling, and repressed by schoolfellows, as so commonly happens—it widened naturally, out even into habit of happiness and joy-giving; and all in the old normal homely way, from helping mother in house and father in garden, into a real and realised ambition, to share in, and learn and understand all in reach of the world's work, and this through appreciative prenticeship to its manliest hand-workers of all kinds; and then under directive experts later. Thus such a prentice quite naturally discovers for himself

that greatest of Socrates' wise sayings (beyond even the psychologic "Know Thyself"); "Labour, and make Music!" In short and simple, here was the education of "the three H's"; by way of Heart, to Hand, and thus to Head. This last—when not mistakenly taken first by blundering mis-instructors and their "educational authorities" so-called, and dulled by "the three R's"—in due season veritably "explodes"—into real use of these too; as Montessori has so well shown. So in the above case, one of the ten appointments mentioned seemed beyond the reach of any youth, and especially one far more trained by practical work than by reading—the direction of an important new scientific library—and was thus naturally deprecated by parent and teacher, on grounds of his inexperience and limitation. But the responsible official replied—"Never fear: I can easily get my skilled assistant-librarians; but the head I want is one who can more really help the readers—like this young fellow, who knows the real things that the books are about."

So much then for regional and occupational education, starting from their vital, their biotechnic side, and thus soon coming to true technic skill, science, and even art; as too much so-called "technical education" still fails to do, since still too mechanistic in method and too simply pecuniary in aim. It is time for real "education for life"—by the way of Life in Education.

UNIVERSITIES IN PROGRESS.—Yet in any social period, and perhaps particularly our own, it is only the very exceptional teacher, parent, or child who can have much of his own way in education. For that is everywhere regulated in the main by the predominant social conditions and their authorities, temporal and spiritual, and these in varying dominance or compromise; and so it is that education has had as yet in the main to follow, far oftener than to lead. For, as every teacher knows and feels, the conditions of the State especially dominate him on one side, and those of the Universities on the other; and these substantially combined into that vast and elaborate institutional sieve-series of examinations, which holds him and his pupils alike so firmly between its meshes, and forces them on from one stage of instruction-drudgery to another. Yet even in difficult times, pioneers have found openings for initiative and impulse, as from Socrates to Rabelais, and again from Rousseau, Pestalozzi and Froebel, to contemporary endeavours now rapidly increasing over the world.

So is it not plain that from kindergarten onwards, and from university downwards, there are freshening signs of hope, and encouragements to endeavour? Yet also that these now need to meet and co-operate before much adequate and general progress can be made, and this clearly presented to parents and public, and to their State authorities in control? Here, then, instead of citing any of the now many schools of good initiatives, let us look for examples

of university progress, and it must be confessed these are as yet hard to find. Here, however, is one peculiarly notable and promising—that arising from the formation of a "Curriculum Committee" by the students of a great American University a few years ago. For students—in our day docile beyond all preceding ones to teaching and examination—to form such a Committee at all, was no small pioneering; for where in history, since the medieval origin of our University system, shall we find the like before? Their Report, too, was well worth reading; and, briefly condensed, came to this:

Our elder authorities insist that we should begin our higher education with the classic languages, literature and history: yet now some tell us that after all, our own vernacular is the main thing; and yet others point out that we also need modern languages. All very good; we admit the arguments of each; yet next comes the mathematician, who assures us, and with cogent argument, that it especially needs his training to develop our minds. Behind him rises the logician, who offers us "the Science of all sciences, the Art of all arts". All doubtless true; yet an alarmingly vast programme: so more of us enter the simpler schools of mechanics, physics and chemistry, which at once continue our school-laboratory experiences and promise us industrial careers. Yet the biologist asks us how we can afford to remain ignorant of life, in its struggle and its evolution; while next the psychologist assures us his is the booming American subject, since the study of mind is the essential way to exercise one's own mind, and to reach those of others. No, it is in my department you should begin, says the historian; and when we ask him—well, what history?—he confidently replies—My period, of course! So too the economist calls us to the burning questions of our present day—and when we ask him—what economic school and system should we follow—individualistic, socialistic, or what?—he confidently replies—You will naturally see the truth of mine! And so on for yet other teaching and subjects—so thus we are but more and more bewildered, and see nothing for it but to think over things afresh for ourselves. With all respect to our teachers, we yet cannot but see that they were educated in the past generation, and mostly offer us what they then learned: whereas we are looking forward to life in the opening generation; and so we feel we need to understand more of the present to prepare for that. Looking about us then, we begin to realise that we are all enveloped within an immense and complex web of human inter-relations and affairs, called Civilisation. So we look round for the professor of that, but cannot find him, to ask our questions—of what it is, and how it has arisen and developed until to-day—and especially what is wrong with it, since it has so many evils, up to the Great War, and to this present discouragement in after-War as well? Again, we see this vast labyrinth of Civilisation is after all included within the vast Universe of Nature: so we look round again for a professor of Nature, but cannot find him either. Disappointed as we doubly are, we yet are clear that it is Nature and Civilisation, Civilisation and Nature, that we have to understand, and in which we must seek and find our education. So, to make the best of it, we now and

hereby give notice to our elders, pastors and masters that we for our part undertake to study more faithfully than ever in such subjects as they teach us, on the clear understanding that they, for their part, make it clear to us what each given subject signifies in terms of Nature or of Civilisation.

A surprising report, heretofore without parallel in educational history; yet hardly less surprising is it to the reader when he finds in a concluding passage, the student spoken of as She! Oho!—he may well say—this is Eve out for the apple again! And when at foot of this long report, he finds only a line or two to the effect that—We for the men students of the University entirely adopt the above report (signed President and Secretary)—the reader can but admire how rapidly Adam follows her example as of old!

Now had this Report been elaborated by students of an old-world University, we cannot think it would have been more than acknowledged and pigeon-holed. But the surprising fact is that this university—no less than Columbia, with its twenty-odd thousand students and eleven hundred teachers—replied with promise and speedy performance: whereby a course on Civilisation, and from Pre-history to the After-war, has since been provided, and this in small tutorial groups, with daily lecture and discussion, thus mobilising no small proportion of the numerous teaching staff; and similarly a comprehensive course outlining the rise and progress, the main methods and results, of the sciences of Nature. Other American Universities have rapidly followed suit, and with increasing encouragement; and similar endeavours are being made on this side too.

Now the essential interest of this great change—this step beyond the extremes of routine curricula on one side, and mere individual options on the other, and yet towards order in principle and freedom in detail—is that here is not only a synthetic curriculum, as some have tried before, but the right one—that turning upon the essential concept of Social Life, for which Nature is ever conditioning civilisation; yet Civilisation is ever mastering and re-determining Nature. Each given Place substantially determines the work and life of its people; yet these People are increasingly re-determining their place. And this formula of social life is exactly parallel to—since socially evolved from—that of all forms of organic life, in which Environment so far controls and determines the life of the organism, and yet the Organism in the measure of its powers reacts successfully upon its environment, and even modifying it. In briefest formulation, the synthetic parallel is clear—using initials for Nature and Civilisation, Place and Folk, Organism and Environment.

$$\begin{array}{c} N \rightarrow C : C \rightarrow N \\ P \rightarrow F : F \rightarrow P \\ E \rightarrow O : O \rightarrow E \end{array}$$

Here then is a better than royal road to education—and to action as well, since an outline for the harmonisation of both. But the reader and we must here leave each other to think out and work out such steps as we can; though developing this fundamental Life-Theory later (Chapter XIII). For the present, enough to point out how this development of university education, by outlining Nature and Civilisation as its preliminary course, coincides in principle with the individual case of an occupational education summarised above; and both with the more general Boy Scout type of Re-Education in its world-wide progress.

SUMMARY AND PLEA FOR EVOLUTIONARY EDUCATION. —How shall we even outline here, let alone fully and convincingly set forth, this thoroughgoing change of educational viewpoints and outlooks, interpretations and endeavours, which we now cannot but demand? Nothing short of reorganised education—Re-Education—accordingly; from Kindergarten to College, Museum and Library; for child and teacher, student and professor, University Principal and Minister of Education—and the public too, with their young folks above all. How shall we even find the word for such a change? Revolution? Yes, thorough; yet with no desire, or even idea, of social changes by authority or by force; our banner is not the urban red, but the rural green. Conversion? Yes, though not with the too individualistic limitations with which that term is apt to be associated; yet as new birth into life sustained by freshening ideal for selves and others, life moralised and intellectualised, to deepened faith and vital works together, and all these vividly imaged with hope, and towards achievement; and this even to aiding the coming of the Kingdom of the Ideal upon earth, as in Ideals at their highest, beyond our powers.

Yet how get over these real difficulties, more concretely and definitely? Recall then in broadest outline the great periods of history which every reader knows. First, the main succession of the Stone Ages, Paleolithic and Neolithic, with their hunting life and their pastoral and agricultural beginnings, the latter with its manifest rise in the status of woman. Next see how, out of their vast burial-places of the past, we are recovering Babylon and Egypt. We have long been under the influence of patriarchal Israel, which, with its outcome of Christianity, ranges from infant teaching to the senior faculty of our Universities. In literature and the arts, in sciences and philosophy, the Greeks have been our fundamental masters; while our history, law, administration, and politics—indeed, agriculture, architecture, and even engineering, have come down to us from Rome. After these classic culture-periods came the Dark Ages, whence emerged the Medieval order, to its great developments, both temporal and spiritual. Yet as these declined

came a new arousal, from further recovery of the classic past, Greek, Latin, and Hebrew; in a word, the Renaissance, with its letters, arts, and sciences; and, for the Northern peoples, the Reformation. With the decline of these two movements came the wider opening of knowledge, as in the Great Encyclopedia of the eighteenth century, and in the corresponding up-clearing (*Aufklärung*) of German thought. Then, too, and in its way vastest of all, yet in and from our own island, came the Industrial Revolution, our age of predominant mechanical industry, with its marvellous processes and technical achievements. Yet these were at first but crudely palæotechnic, with many of the reversions that term is chosen to connote, since back to utmost individualism of the hunt-struggle, and its application to mere gain, and forward to utmost man-huntings called wars; and these still perfecting towards destructiveness, as neotechnic science and skill equip them. So now our outline retrospect is up to date.

But as yet even those disillusioned of the progress of the paleotechnic order, by its evils, too simply agree with its votaries, still the mass of our modern public, that we need but more charities and more palliatives there, and such and such other improvements, to enjoy health and wealth in peace, and all assured by political progress and power, as up to Hague Court, League of Nations, Kellogg Pact, and even Mr. Wells at his best looking beyond them. With enough of these palliatives, improvements and controls, our industrial age—with progress, of course, in its efficiency and rationalisation, and also with its present education activated and diffused, in short, its Neotechnic phase—may thus be assured in prosperity and world-peace.

But here increasingly, we students of life and its sciences can but say—So far, so well—yet far from enough! For this modern culmination of the Industrial Age, and with all its progress, is still essentially based upon the mathematico-physical sciences; and so is failing, despite all its clear thinking, its discoveries and inventions, often so helpful to us. For of a civilisation ever more and more dominatingly mechanistic, and thus developed without adequate science or practical ideal of Life in Evolution, who but Death can be its essential master?

But to do justice to the industrial age, and the mechanical culture, let us seek it, hear it, at its very best. Where then shall we look for the most expert, the most authoritative and most comprehensive survey of the industrial age, and throughout its advances, from its early and palæotechnic beginnings to its present neotechnic mastery? Obviously, among all quarters of the world, we may best return to the British Institute of Engineers who have conspicuously led this, even in the main created it, though others, as from the Continent to America, have aided them, and are now often advancing

and carrying out their main inventions on yet greater scale. So for their recent Centenary Celebration, they wisely elected as president and spokesman Sir Alfred Ewing, as their most experienced and widely cultivated mind, one long eminent in engineering and physical science, and of unique career in the War, yet also in education as well, and from that of the Navy, to the principalship of a great University. Hence the best possible presidential address; and on the right subject for our recalling here, the survey of "A Century of Progress". Yet when this masterly discourse, with all its legitimate pride of commemoration of notable advances, comes to discuss the main social results of this upon its century, it sounds as deep a note of pessimism as ever did Carlyle, Emerson, and Ruskin half a century ago and more in fact, practically renewing these, and going beyond them. "For it is the engineer who, in the course of his labours to promote the comfort and convenience of man, has put into man's unchecked and careless hand a monstrous possibility of ruin." Yet while recognising how such material progress has so far outstripped the ethical progress of the race, and even looking around for such needed agencies, he can but vaguely hope and grope for them; not realising that even in his own University, let alone others, and the larger thinking and working world beyond—and in this, and not least, the women—many are nearing the needed answer, since more and more clearly raising its question, even to the cry—Beyond all this Mechanism and War, how find the way to Life, and Peace? And our answer is—through life!

Busy though are biologists and psychologists with their respective problems, and these so numerous and intricate that these bulky volumes can be but a very incomplete introduction to them, even from the biological side, it is thus time for them to be facing this widest of general questions. How best do this? First of all through realising that as the fullest life of any organism is that which best expresses and advances the life of its species, so we workers on bio-psychologic levels fall short, until we subserve the social life, which in turn justifies and stimulates our labours, and utilises them.

Briefly outlining then this outlook, and leaving its detailed argument to our sociological papers, our essential proposition is—that this incipiently Neotechnic Industrial phase, still fixed by its mechanistic and pecuniary culture, and thus responsible to physical and arithmetical science wellnigh alone, has now to be increasingly guided into Bio-technic service, and by Psycho-biologic thought; so with subordination of its struggle for existence at all levels, as from individual business to international and civil War. And this by turning towards the Culture of Existence, and so with renewal of that life-tending advance—itself preponderatingly feminine, yet masculine too—which has been clearly manifested from pre-history onwards, and in varying measure up to this day, and has also been

fundamental for organic and psychic evolution. Witness that of ants and bees from lower insects; and, beyond all, that of birds and mammals from reptiles—in each case through mothering and parental care, in nest and bosom.

Here be it noted that Darwin's doctrine of "The Origin of Species by the Preservation of Favoured Races in the Struggle for Life", as his title-page has it, was perfectly clear as to the above main view of evolution. Yet through those two past generations of the industrial age, from Tennyson's presentment of "Nature, red in tooth and claw", to Nietzsche's rhapsodies of contempt for the more gentle and truly evolutionary virtues which his sickness and "Weltschmerz" made him caricature as mere weakness, the public have mainly had such mis-popularisations of the evolution process; thus coloured, of course, by the contemporary growth of mechanistic struggles in peace and war, by turns and together, and in fact pervading the whole atmosphere of the Industrial Age. But now, with our evolutionary outlook, clarified by advancing science, and by experience of War and After-War as well, we are certain and assured, alike on biological and in social levels, of the superior survival-value of the Culture of Existence—as notably by the smaller peoples outside the war, as compared with the struggles to the death of the Great Powers that were in it; in fact, just as we are sure of the present survival of birds and mammals, for all their smallness and weakness, compared with past reptiles, with all their size and strength. Why, it was the Reptilia that, so lately as Cretaceous times, were the Great Powers! They had the colossal size and strength; they marched resistless, like tanks, and even bigger; and they often were armour-plated as well. They were masters of sea-power, as well as land. Some of them actually were aeroplanes, so could fly yet more amazingly than we do. And as for tooth and claw, they hold the organic record: so how could they give a thought to the then smallest of powers, our tiny rat-sized great-grandmothers, who could but dive into their holes when the great feet tramped near, or the great heavy tail, carelessly dragging, coarsely crushed them there. But where are the Reptiles now? Fossils in their slime, hardened to rock; or in our museums at best. Yet alas, also re-incarnated, as the Hindu and the theosophist would say, in their modern successors, the yet more colossal mechanistic and mammonistic, megapolitan and megalomanian—and thus inevitably militaristic—"Great Powers" of our day. Far as yet from extinction, they think; yet nearer that than they see. For why did their reptilian prototypes die out, despite their magnitude? We so far know now; for we see that though their bodies grew too big, their brains remained too small; and that was the end of them.

Yet, after all, we mammals, and the birds too, are of reptilian

descent. Yes, but from their Small Powers, not their great; those that developed not so far mechanically, but further vitally, and in life's higher functionings. First of all by care of young, and this through lengthening of infancy—in mammals especially, and in man almost most—and thus with more brains, and these keeping on growing and active, and so through lengthening life, and with keener senses too. And so with more use of their limbs, as for better locomotion, and greater speed. Handier use too of their paws and digits, by and by hands and fingers; and with more use of their eyes, sensitive noses, and even of their teeth, all so often put to other uses besides fighting and killing. They grew, of course, but to more moderate size; and so needed less food for upkeep, with rare exceptions. And with all this, fuller life; and greatly advancing it, the active body became warmer, with circulation more efficient, and better regulated by a stronger and more developed heart, and by finer vaso-motor adjustment. Preserving this warmth, their epidermis grew hair-filaments instead of scales; and in birds the scales thrilled out into feathers, and grew to glories of paradise-bird and peacock. And with all this developing beauty of birds and mammals, came their new—and wholly post-reptilian—wonder-life, of sex and courtship and song. And thence again to family life, in homely nests, and nest-like homes. And thus to sociability for many species, and this vital, intelligent, often joyous, beyond all solitary life-forms. Next up to the sociability of man—which, beyond all arrests, all reversions or perversions, is still advancing. Is it said, this still at times is monstrous? Yet despite all drawbacks or throw-backs, our evolutionary science gives us fullest hopes; since life's greatest pre-visions in the noblest past—as of Olympus and Parnassus in one age, or of sanctity and chivalry in another, are but ideals of body and mind at their best; and which thus necessarily reappear before us, as aims not only rational and legitimate, but, in all highest senses, necessary ones.

Increasingly discerning and utilising the long tradition of Life, and of Humanity as rising to its social and individual best, with due selection and guidance of their variations as well, it is plainly again becoming possible for each family and neighbour-group, each region and city, each larger culture-grouping as well, and with due regard alike to vital and social inter-crossings, to set about raising its struggle towards its Culture of Existence. In such ways the current conception of "Progress", so far too vague, when not too limited, can be increasingly clarified and developed, in terms alike of Evolution and Education, increasingly at one. Indeed, is not this latter conception the simpler and clearer of the two? So utilising all the best that nature and nurture can give us, we learn to aid our successors to socialise, moralise, intellectualise—and thus creatively individualise—Life yet farther, in fuller and more vital interaction

with environment at all its levels, material and psychic, and from simplest to highest. As we thus more fully live in such human co-operation, of hearts, hands, and heads in advancing harmony, the Eupsychia, Eutechnia, and Eutopia of Re-Education, so often dreamed by thinking and pioneering teachers, become increasingly realisable goals for progress; oscillant and asymptotic though that may be.

BIOLOGY AND SOCIOLOGY

Biological Modes of Thinking Socially Applied: "Durée." —For an orderly presentment of these, we should need a long chapter, beyond that fundamental parallelism of organic and social life-processes already expressed, and some briefer suggestions elsewhere in regard to Time, and "Durée". Particularly significant from the biological viewpoint, is the importance of time, as of years and seasons, and even months, weeks and days; and also on the larger scale, as with the rings of a tree, which so plainly embody and record its years, and often even seasons, with their vicissitudes; as similarly for the growth of shells, of fish-scales, etc.; while in the life of higher animals, and of man, of course above all, the curve of life is well marked out into its main periods, as that of human social life by its changing generations. Here, then, conveniently arises, as common to all life, from simplest and briefest to highest and longest, M. Bergson's conception of "*Durée*". Why is it so difficult to translate this word? Every stone has had long duration, yet no *durée*, though in its place, whether in Nature or in the wall we may build it into, it may still endure for indefinite ages. We have thus no English word to convey the idea: why not follow the custom of our language, so open to imports and their adaptation to our needs, and simply say dury?—just as we have already done for jury (*juré*) and much the same too for fury (*furie*).

At any rate, let us see clearly what Bergson means by it—or, for brevity's sake, simply use an illustration which has pleased him. Ask then a child in English—How old are you?—and note the answer.—I'm ten past.—And your father?—Forty!—Your grandfather?—He's long past seventy. Now the like in French. You ask: "Quel âge as-tu?"—"J'ai dix ans et plus."—"Et ton père?— "Il a quarante ans."—"Et mon grand-père a bien plus de soixante-dix ans." The translation seems literal enough. Yet in English we are mainly thinking of astronomical years, past and gone, which we have no longer; whereas in French, we *have* our years. That is why the child is a child, since it has so few; why the father is a man in his prime of activity, and why the grandfather is richest in experience. The French idiom in fact implies *durée*; but the English one,

though, of course, not excluding that idea, manifest on reflection to every mind, does not so simply and adequately express it. So we may think of M. Bergson as a French child, though the first one fully to realise this advantage of his language, and clearly to express it. Like the tree, and far more fully, we have our years, with their accumulation of organic growth and change, and of psychic experience and development; while the stone can but endure external changes of its environment, or weather away from these, but lacks that true registration we can but call dury. In social life we commonly speak of this as History, but the better term is that of social Heritage: and hence we value it; as materially from laboured soil and spreading trees to well-kept home and treasured heirlooms, and so on to monumental cities. Yet as fully can we appreciate our less materially embodied heritage, as of language, literature, and music, of family, local, regional, and civic tradition, of institutions of all kinds, with their distinctive values. Throughout these vast heritages of all kinds, there are few or none wholly without elements which have (or may) become burdens, sometimes even evils, needing elimination—say oftener replacement, appropriate to present or opening needs. It is thus profitable to consider individual development and human evolution alike in terms of Dury.

Biological Changes Paralleled in History and Institutions.—For the history of peoples and civilisations the idea of growth, maturity, decline, and even death, is one of the most familiar and well-worn ones; yet under active discussion again to-day, since Spengler's *Decline of the West*, even to its down-going as he literally threatens. But avoiding this vast and dubious discussion for less extreme social changes, we shall take here but a single and simple biological illustration, that of the beautiful "Peruvian lily" (say, rather, amaryllid), with its leaves sharply turned over at their bases, and re-adapted accordingly, so that what was the normal upper surface, has not only acquired the general aspect, but the functional stomata of all ordinary leaves. Correspondingly, the former under-surface, now the upper one, has fully acquired the aspect and character of that of ordinary leaves. The adaptation of original structure to functional change, so frequent throughout Nature, is thus presented here in the simplest diagrammatic way.

So what simpler and clearer illustration can we desire than this, to bring out the frequent analogous contrasts which arise in human societies between things as they were, and even commonly are, and things as they change? The original under-surface, still manifest at the base of the leaf, is, for the morphologist, clearly still the under surface, no matter how turned over; or even were it twisted into a screw (as some Croton leaves are!). His case is clear, at once "Legitimist" in history, and unanswerable in strict law. Yet the way of

life has changed; so how can either historical or legal discussion affect it? *De jure* now practically matters nothing; *de facto*, the matter is settled. "Law" and "Equity" here are contrasted, like Jacobites and Hanoverians; for when an ancient regime has gone we must make the best of the new, until its time and turn for change may appear in life, and justify itself accordingly. The botanist, as gardener, may and does control or redress many external changes: he can guide growth, he can propagate, graft and bud; but he can have no idea of meddling with this Alstrœmerian revolution, or rather overturn, since that has been decided by its life, and directed from within.

MAN AND SUPERMAN.—Though much has been written, and more talked, in recent years on this theme, the wonder is that it has not gone much further than the dreamlands of speculative or imaginative writers, and without yet winning its legitimate place among the problems of evolutionary science, inviting inquiry, scrutiny, and survey; and also practical measures, even beyond eugenics so far. Such evolutionary endeavours must involve observation wider than ever, whence in time generalisations and interpretations, extending to foresight, and rousing to practical measures accordingly. In briefer terms—vision as observant, vision as intelligent, vision as future, vision as becoming realised—so, at briefest, *Voir*, *Savoir*, *Prévoir*, *Pourvoir*. We cannot, of course, attempt to outline all this, but it is worth doing—and far more fully than as yet attempted, since nothing short of a co-operative stocktaking of life and civilisation, and their possibilities, and towards policy accordingly.

The traditions and literature of every people and period are rich in records and tales of their illustrious individuals; and even when these are not veritable, or even seriously credible, they often all the better illustrate the ideas and ideals of their times. Seriously interpretative biography, beyond past standard examples, is now advancing towards a sounder technique, reinforced by bio-psychological and social standards. The eugenist and the educationist have here also to combine their too long separate perspectives; and this is not so difficult as it has seemed, whether in Life-theory (Chapter XIII) or in actual practice. Witness the ordinary complemental meanings of "good breed" (as eugenic), and of "good-breeding", "well-bred", etc., as implying well brought up; while "good family" may be used in either sense. We need both.

This subject of further human evolution is thus not limited to any particular Utopias or their Utopians; and though such literature is not to be despised, we may well refrain from adding to it, other than may arise on the bases of scientific inquiry and practical policy. We must start (1) from what we know of the past, (2) of

where we now are, and (3) in what direction our different groups and communities, our civilisation-phases and processes, are tending; after which our approval and concurrence, or our criticism and endeavour towards change, will have substantial grounds. The opportunity for the advent of the superman is thus more a social than a biological one. Let us see what of old he seemed.

First then the traditions and the fertile imagination of the ancients have here far surpassed ours. The mythic past, and yet more the theologic systems so deeply meditated from of old, have evolved an immense variety of presentments of more or less ultra-human and super-human types. Witness, on simpler mythic levels, the Olympians and other deities of Hellas; and from the triadic unity of Elephanta cave-temple to the "thirty-three crores" of Brahminical surveys—as many as the present population of India! Again in the strictly monotheistic systems of Judaism and Islam, there are archangels and angels, seraphim and cherubim on the psychologic level; while in their human tradition, patriarchs and prophets are rightly honoured, as supermen none can fairly refuse to recognise. Christianity too has incorporated all the preceding; hence Dante, or Milton so vividly recalling "thrones, dominations, princedoms, virtues, powers". In history and biography it has exalted, and not without reason, its founders, as from apostles and evangelists, doctors of the church and heroic martyrs, and its variously influential and exemplary types as well; hence with institution of saintship, honoured and continued to this day. Here, then—as well, of course, as the mythic and historic heroes and heroines of all peoples—are supermen of all kinds and types.

With such wealth of examples, how is it that science has as yet so little to say? Harrison's "Calendar of Great Men" is the fullest outline-attempt at estimate of the world's leading men of genius throughout the main fields of thought and action; and though, of course, there are many fuller special and historic outlines, with more or less interpretative biographies, and also not a few attempts at interpretating the psychology of "genius", as by Ostwald, Nordau, etc., these still remain insufficiently related to ordinary life, and thus lacking in guidance for its development. So far, then, the question of the "mute inglorious Milton" remains unsettled. Let us consider it a little farther.

GENIUS AND ITS DEVELOPMENT.—For the religious world, the needed illumination is of ancient date: "The kingdom of Heaven is within you!" Does not this apply more widely? Discouragements have naturally arisen, as reacting from the perfectibility preached by Rousseau and long surviving him; and also from subsequent social conditions, in many ways less favourable to individual development than was anticipated in a world of confidently assumed all-round "progress"; so that many now seem more sure of the

coming of Capek's "Robots" than that of Nietzsche's "Super man". Anatole France's pessimism over all such utopias of advance may be extreme; but there now seems less of sanguine hopefulness from education, or even from eugenics. For Nature and Nurture, as the two main and complemental sides of life, do not yet find adequate experimental trial together. Pending such developments, we must return to the simpler conditions of individual development and community evolution. May these not give light towards higher ones, if not even suggest leading as well? First, then, let us throw aside the conventional social assumption of "the average man", and start anew from our organic and psychic uniqueness, as in face and form, even to thumb-mark; and in functional ways as well, as from voice and gesture, written or other, to "Character" as a whole. But where and when social conditions inveterne, as in our own day, to standardise these to some externally imposed "good form"—be this in school, factory, barrack, or prison—the effective result shows much more of restraint than of development. Hence it is instructive to note how very many notable men of genius—the supermen of the past century, for instance—have to be understood not as the successes claimed by these orderly systems, but rather as their survivals; or, still better, as their truants. Here the biography of Darwin, arch-truant of his school and of his two universities, and then world-traveller, is not a little significant; and this the more since it was his mind, thus free, yet rich in observation and vital experience, that stated and developed most fully the general concept of organic evolution, with its most convincing of partial interpretations, and with its most effective evidence. Many similar illustrations of the like advantage of freedom for genius might be cited. Given freedom to find, follow and develop one's inner interests and impulses, and thus form good habitual bent—and this pursued with patience, yet not without leisure and change—ideas arise, often as flashes of vivid illumination, yet also by slow growth. And the like for creative invention as for discovery; in fact, for initiative of all kinds, and each a step for personal development, and often also for social progress. Here then re-appears our pragmatic summary—*Vivendo discimus*.

But such cases of genius in freedom are very exceptional! Yes, while our social institutions keep them so. Yet see how youth finds outlets from these, as with varied sports, and their innumerable record-making and -breaking achievements. See, too, the decisive Battle of Education, between the 50,000 Boy Scouts not so long ago assembled near Liverpool, against the traditional schools and their militant corps. On the scout's arm note the badges of the many occupations—all educative in their own ways, which he has chosen for something of real prenticeship, and always without pecuniary inducement, but with that of incipient efficiency of manhood. It

s not too much to hope that from these a higher proportion of genius will emerge than from the schools of good form and conventional instruction. Until these schools have fully awakened to such vital experiences, and give these even better, and so produce youth no longer left unemployed, and too often all but unemployable, but ready to go anywhere and do anything, according to the lights they have thus reached, and the worthy tasks of life they have been helped to see.

Note again corresponding beginnings on the psychological side, already approaching record-making and breaking also. The growth of "Correspondence Schools", as of "Pelmanism", for single example, is for us of the universities to look into, as indeed in France is now happening, and with noteworthy advance. From Montessorian and further methods of developing and training the senses, with well-chosen and varied occupational experiences, and these leading to clearer ideation, there also comes vitally social experience; leading no longer to narrowed individualism, but through social service to socian individualities. Also there is in progress here and there a rational organisation of knowledge; and even a command of its heritage, as up to its universal and usable bibliography; hence such movements must soon involve the substantial advance of higher education. And this not only through the charting and re-unification of the specialisms of knowledge, as from concrete details to comprehensive and graphic unification of these, but with corresponding intellectual command of them as well, and thus aiding fuller efficiency and fresh applications. For an example, see how the principles of evolution, in its widest sense, are applicable broadly alike throughout inorganic and organic nature and in the world of man as well; as from crafts to arts, from languages to literatures, and from manners and customs to bettered laws, and even to morals, with its ideals inspiring the whole.

The real sense in which all admit that we moderns surpass the ancients—not necessarily in sheer native powers, for which we have no evidence, but in command of heritages in some ways beyond theirs—may thus, as it is developed and diffused, evoke a far larger proportion of super-normal abilities and achievements. Einstein has never claimed superior natural powers to Newton's; but there is no doubt that he has surpassed him; and in the thoroughgoing fermentation of all the mathematico-physical sciences now in progress, an amazing constellation of productive genius has been manifesting itself, indeed year by year.

Such examples might be multiplied, and from many other fields of thought and action. So that as evolutionists pass from their many and long preliminary tasks, of inquiries into Origins, human and other, and set out towards the discernment of evolutionary Tendencies as actually manifesting themselves, albeit with too little

co-operation, and so next turn to their better organisation and guidance, there is little fear but that the world-crop of supermen may be increased and improved. And why not even here and there stabilised, by eugenic and other agencies as well?

In short, then, the Superman is within us, however imprisoned; it is his arrest that we need most of all to inquire into; for our brains are much larger than we yet use. So our children's hands are more adaptive than we know: thus the recent emancipation from standardised mis-instruction methods is clearly proving that most children have been restrained from being true artists. And as their hearts too are here and there set free from the chilling individualism still so firmly imposed on most of them, what growth of fellowship, and thence of individuality as well! Why not even to "la politique de bonne humeur", i.e. towards gentle, peaceful, and yet intensive and extensive, transformations of our existing confusions and hostilities, and towards better, fuller, and higher phases of social life. In such ways then, the apparently remote and difficult advent of the superman may be accelerated. Above all, by the release of latencies as yet too generally repressed; though necessarily with self-discipline as well; and social encouragement too, instead of present hindrances and restraints. Such needed changes and opportunities are matter for social studies and initiatives; but enough here if we see grounds for reasonable hope and endeavour towards practical furtherance of developing individualities, and in the service of social evolution; and these as its leaders, and not as master-castes restraining it. If so, it is thus open to us as evolutionists, thinking towards a world of hopes anew, to imagine them as boldly as have our predecessors, even to Parnassolympians in Eutopia, or such yet higher imagery and aspirations as may be. And why not even discuss lines of action towards realising these? Are not some of them before our eyes?

Yet not to leave this question of the superman on utopian levels, or of merely individual and bio-social suggestions, we may now turn to the current literature we put aside at the outset, and make brief citation from an American artist in letters, living and thinking, as sympathetic critic, in the varied modern art-effort-centre of Paris. Hear then his claim, and call too of evocation, of the superman, in and as the super-artist:

> The artist, in my conception of him, is the most severely responsible of men. More and more, as superstitions and theologies fade, he becomes the chosen mediator between man and that totality of human experience without which the spirit withers. The artist becomes priest. The great artist always has been one. The artist seeks the way, lives his truth creatively, moulds life anew. If he does not keep step with his fellow men, it is, as Thoreau has finely said, "because he hears a different drummer".

Or if the above seems still utopian—as vital thought in our still

mainly palæotechnic world so largely must—let us turn again to education; for at least some possibilities of development are obviously latent in each and every individual not wholly defective; and other possibilities may still be there, but undiscovered. The kindly care and skill of woman has increasingly been demonstrating this; for the new advance with Montessori is but one of the recent triumphs we might cite of feminine sympathetic insight, skill, and patience. The improved defective is thus henceforward a superman compared with his former too merely animal self; hence that exclamation of the school-inspector which went round the press of the world and suddenly made her famous: "You, madam, are making defective children normal, while in the schools we are making normal children defective!" How this latter statement is but too true, and how development is so comprehensively arrested (see Tagore's *Parrot's Training*) we may consider elsewhere. Enough to note that it largely explains the present scarcity of supermen, on primary, secondary, and even higher education levels, and whether as teachers or products. But as we imagine, and make, some experimental endeavour—or at least observe the methods and results of the real educators who are often struggling in the most conventional schools, colleges, and homes—we come to see how reasonable the hope of releasing the superman—of whom elements are still latent, even in the most "well-educated" into conventionality (the real meaning of "ordinary" and "average"). But for this we need also—far beyond even current eugenics—the help of sociology, and with all its psychology and ethics, and so here again leave this hope to further elucidation. Let us foresee and aid, not discourage, the fuller arousal of the generous ardour of youth's, woman's, and man's emotion, ideation, and imagination, towards collective and individual achievements, upon the deeper and higher levels of true and constructive peace; for which the Superman in each is so urgently needed; and indeed thereby so far realised.

THE BEAUTY OF DEATH.—So far as we know, even the great funeral preachers have seldom spoken of this; painters have seldom portrayed it, save as in Pieta; and poets seldom too; yet who can forget Byron's true and moving lines: "What rapture and repose!"? Not these invariably, alas; yet it seems frequently; and these exaltations may be of very varied kinds, and sometimes extremely, even amazingly, developed. Thus one remembers a face which in last illness seemed but that of worn-out, withered, and wrecked senility, transformed to sublime; and another formerly plain, weary old woman rejuvenesced by forty years and more, to happily sleeping young bride; so that her own brother, family, and friends could hardly believe their eyes. In hospitals, too, one sees kindred change; and in our (admittedly not great) experience, it seems fre-

quent—perhaps oftener with women than with men? Would it not be well if some psychologically-minded physician would study such cases, and with photographs? Here plainly is the justification of "lying in state"; that all may see the face they know and mourn, thus often at its best, and sometimes beyond that altogether. May not such ennobling and beautifying help us to understand the ancient endeavours to preserve the body by embalmment; and to prefer burial, in the west; yet also, when viewed differently, the preference for burning, so widely practised in the past, still in the East, and now anew in the West as well. Indeed, may not this change, so often to or beyond the best we have seen and known in life, be one of the factors in developing, diffusing, and strengthening the conception of immortality, and at its best, with "forgiveness of sins", and hence beatitude?—since such dead faces seem transfigured by the soul, and at its very best, at length realised.

What of simpler physiological explanation? That death is not so certain as it may seem, is the reason of leaving certification to the physician; and he, too, may sometimes err. That those apparently drowned, and past ordinary methods of resuscitation, may be recalled by Schäfer's improved method, is now also common knowledge; and the fact that a man's beard may go on growing for some hours after manifest demise must have been noticed from time immemorial. What we note as "the moment of death" is that of the fall of "the tripod of life"—heart, lungs, and conscious brain—but the other organs and tissues yield more slowly. So surely does not the sub-conscious life depart more slowly too? Indeed, when it is thus relieved of central control, and left to itself, must not the body, even more than in ordinary sleep, have thus brief time for its sole influence, and with such partial growths as well. The muscles of facial expression are now for the first time fully released from their control by conscious life, with its cares, its ordinary habits and their expression; so now, for first as well as last time, since sleep of infancy, the face is fully "sculptured from within"; and this often to essential character-revelation at its best, however heretofore repressed, yet latent, and, as we see, potential; or at most seldom and briefly revealed—as to a single companion at highest moments of love—but now soothed to serenity, deepened even to ecstasy? Indeed, is not this last beauty-sleep a final and consoling revelation that "the kingdom of heaven is within you"? Or, in modern phrase, a final—yet rationally to be considered—evidence of "the superman", latent in each and all? If so, is it not possible to seek out the ways and means, both old and new, of such arousal, before too late?

RELATIVITY?—In these times thinking people, each more or less imbued with the ideas supplied by the secondary and higher education still for the most part prevalent, and by the

everyday world of discourse also—are striving, and this more and more anxiously, to understand the very nature, and the bearings also, of the recent and current transformations of what they have so long been accustomed to think the scientific and rationally established theory of the physical Universe, ranging up to and through the solar, stellar, and nebular systems, of which our knowledge is ever being extended with increasing telescopic powers, and also more and more deeply interpreted, in turns by mathematical and spectroscopic advance. But behold, our Newtonian Universe is shaken, and to its very foundations; since in space, time, and movement alike. Space and Time, we are now assured, can no longer be considered absolute. Not only is our Euclidean geometry of three dimensions, as indeed was first shown wellnigh a century ago, only one amid a choice of new geometries without number; but a new and seeming difficult conception of "space-time" is pressed on us; in which our simple conception of time is often spoken of as a "fourth dimension", into which we feel called on to enter, and so dutifully strive to twist ourselves, despite puzzlements and pains. Space and time, which are taken as absolute in Newton's *Principia*, so long esteemed the most convincing of all the achievements of science, are now presented as "relative", in ways which alarm us as mathematically profound, and beyond our past level of education. Yet thus has arisen a reinterpretation, not only of gravitation and its outcomes, but this through criticism of Newton's main conceptions of the whole astronomic, spatial, and dynamic universe; which is now in one sense limited and yet in another sense limitless; so with rearrangement of our associated concepts, and these experimentally verified in test-cases; and thus victoriously compelling our acceptance. For associated with such transformations of our conception of the Universe at its greatest, there has been going on a corresponding revolution in its minutest and most intimate analysis. Thus consider how from antiquity we have thought of this analysis as ending with "atoms"; and next with these made clear for us by Dalton and the century of chemists who have followed him, as so many definite elements with vast possibilities of combinations, but themselves ultimate. These have long been so far arranged indeed, even into resemblant groups, and in rhythmic and harmonious series; yet none the less each retaining its own permanent and distinctive characters. But now this apparent ending of our analysis of nature has proved to be but a new beginning; for these "atoms" are now taken to pieces, and proved to be so many microcosms, as from the single proton and electron of the hydrogen atom to the vast complex of 238 of each which we call uranium; while, stranger still, we find this to be in process of a long and serial disintegration, and through phases from slow to swift; and these as a series of veritable transmutations,

strangely recalling what have so long seemed the dreams of alchemists. Among such elements, both new and old, the amazing radium is but the most accessible for varied experimental studies, and these in many directions; as from cosmic reinterpretations by terms astronomic and geologic, physical and chemical; and even to specific applications to diseases hitherto unconquered. Prout's hypothesis of a fundamental unity among all kinds of matter is thus strikingly confirmed; yet that permanence which seemed so clearly demonstrated by Lavoisier with his balance, and verified even to atomic weights, by subtler weighings, is thus deeply shaken. We have next to face no less serious changes in our conceptions of energy. The particulate light emission doctrine of Newton seemed definitely superseded by Huyghens' theory of radiation as ether-waves; while the incorporeal nature of heat was made even more plain and clear. The speculative insight of Faraday as to the nature of electromagnetism was not only mathematically confirmed by Clerk Maxwell, but correlated with the interpretation of light. Including and correlating all forms of energy, the sublime doctrine of its conservation was gradually elaborated by many of our ablest scientific brains, all the way from Mayer to Kelvin and his peers in the same and kindred fields, and with corresponding fertility of applications. Yet despite the many and brilliant advances in the study of electricity, as from Gilbert, through Volta and Galvani and many more, to Kelvin and his successors, the essential nature of electricity remained unexplained; whereas now, to make its long story short, our contemporary physicists have not only come to treat it as particulate, but applied this conception to the reinterpretation of the atom itself, since with the central protons as its "positive" and central sub-atomic unit, and the surrounding electrons as "negative". The long and varied endeavours towards forming a consistent conception of the nature of ether, so ably postulated and applied to meet the needs of the undulatory theory, have yet also failed in other respects to attain consistency among its assumed properties, or experimental verification of seeming essential ones: hence, despite the partially explanatory value of each endeavour, most physicists are now depriving us of its aid; so that we (and they themselves) cannot image physical processes as clearly without it—yet also not adequately with it either! Hence we fail to attain the clearly visualisable imageries of mechanical working on which Kelvin especially insisted as of the very essence of clear physical thought; so we are now often offered but mathematical expressions, and these beyond our ordinary powers; and which even their potent formulators confess they cannot fully translate into the physical imageries our concrete minds desire. Yet to take an example which we can faintly attempt to image, we are assured that the apparently clear (and doubtless so far con-

tributory) explanations of the vast solar output of energy, which were offered by Kelvin and his contemporaries, are inadequate; and that we have now to conceive the enormous disintegration of solar and stellar matter into the energic torrents of radiations which all these suns so demonstrably, and so far measurably, emit; so that Kelvin's "dissipation of energy" reappears in a fresh form, with dissipation of matter as well.

Enough, however, of these stupendous transformations, even transmutations, of what seemed well-established science, which have been and still are in progress in this current century; with reinterpretations of our Universe, alike on vastest and on minutest scale, and these in fresh and surprising inter-relations; and on principles revolutionary throughout wellnigh our whole range of past conceptions. It seems time therefore to be facing the corresponding human and personal question—that of the significance of all this transformation of our ideas regarding the physical world, in relation to our ordinary thought and life. What are the bearings of these, and what may be their effects? How far have we now to readjust—if not even re-form—our long-current ideas of life, and this not only organic but also psychic, not only individual but social? Since every historic religion has been associated with a cosmogony, and these alike have to be considered by philosophy, so again, to the religious mind and to the philosophic alike, this new cosmogony of the mathematical physicists and astronomers is insistent and even clamant for consideration.

These pages are indeed being written the day after the close of a ten days' symposium (one of the notably active "*Decadis*" held each long vacation at Pontigny), in which a series of masterly expositions by an eminent astro-physicist and mathematician, peculiarly at home in the above-indicated fields of inquiry and progress, and supported by mathematical and other expert colleagues, have been eagerly and actively discussed: and this especially by humanists, from historians of thought in its changes and controversies, to philosophers of kindred interests, and from thinkers on comparative religion, to teachers who have to meet the varied inquiries of their students, by turns touching all these fields, cosmic and human. Each and all of us have thus been united in the common desire of attaining some consistent and comprehensive conception of the Universe—an "*Imago Mundi*"—and of discerning its bearings on the life and thought of our times. A difficult matter, yet one which no healthy and active mind can be content to abandon to mere negation, or to indifference. Hence the slow and difficult acceptance of the Copernican theory, and of the teaching of Galileo, was carefully discussed, and with fresh historic light. The last century's difficulties of readjustment, in face not only of the rise of geology, and the proof of the antiquity of man, but also the doctrine of

organic evolution, with man's animal descent, the rise of his psychology, etc., were more lightly touched, but not forgotten; and it was felt well worth while to have at least prepared for discussion of such large questions more comprehensively and fully at the corresponding gatherings of coming years.

BIOLOGY AND RELATIVITY.—Now however for the problems of biology in this connection. What of all this mathematico-physical revolution for and from the point of view of the sciences of life?—since these have loyally to acknowledge the fundamental contributions of bio-mechanics, bio-chemistry, and bio-physics in the past, and must remain open to such further contributions as these may make in the future. Coming however to the most general of questions, it is peculiarly interesting to note that the rigorous determinism hitherto so characteristic of the physical sciences is being questioned by the physicists for some of their latest developments; so that the traditions of physical determinism and physiological "materialism" are so far being shaken. Even beyond this, it is remarkable that so relativist a physicist as Eddington, and apparently not as solitary instance, should be speculating on the correlation of his ultimate view of matter and energy with that of "mind-stuff"; and again that Whitehead should be initiating "an organismal conception" of intra-atomic functioning.

We cannot here discuss these speculations, yet it is important to note that their authors present them as a beginning of a new trend in physical science, in fact as from its past philosophy of determinism towards one admitting something of freedom, if not even passing towards a new movement more or less idealistic. But this we may best leave for the present to the physicists to whom they are primarily addressed.

BIOLOGY AND TIME-QUESTIONS.—Enough here to say a word or two from the standpoint of the biologist. As for the so-called "fourth dimension", of time, what for him can be simpler than to recall the physicist's attention (sometimes in our experience seemingly curiously forgotten) to the familiar aspect of the nearest tree-stump, with x and y co-ordinates as cross-diameters of its plane circle, each so plainly modified by t for time, since the number of "rings" expresses its annual growths; and next to realise how in longitudinal section, the tree-stem also obviously yields us as many annual cones of growth, with the vertical co-ordinate, of z, as axial. So the resultant form is plainly that of $x \times t$, $y \times t$, and $z \times t$; yet all this is still in the three familiar Euclidean dimensions, and on the three Cartesian co-ordinates accordingly; so without the difficulty of thinking of t as an independent dimension, but simply as increasing all three, as plain folk have always seen. Here, too, is a similarly elementary image for the Bergsonian *durée*, as similarly is the growth of a shell, or a fish-scale. And even though

we now substitute any less obvious organic structure and development—say the growth of the human thigh-bone, from babe's to giant's—the same fundamental inter-relation of the three Euclidean space-co-ordinates with their associated time-increments, remains sufficient for us, though we now see these form-changes as more complex; since involving un-building, in time, as well as up-building, and with these negative and positive growth-processes going on together until maturity is attained. The understanding of this complex organic growth process may thus be a convenient introduction to the difficulties of social growth as well. "On ne detruit que ce qu'on remplace."

Now another simple biological criticism, which may be unfamiliar to the physicist and his perplexed students, namely this: that, when all is said of these changes to relativity for the mathematico-physical universe, we simply see these as broadly parallel to, and harmonious with, that way of looking at the organic world with which we have long been familiar! For it must be clearly noted that Newton's absolute space and time were but part of the general system of reference also applied in his day to the organic and human worlds alike, since these were also assumed of practically simultaneous and definite creation. This indeed was set forth by Linnæus, in his conception of species as separate and simultaneous creations; which he expressed soon after Newton's day, in that still classical and long authoritative *Systema Naturæ* which thus in its way corresponded to the *Principia*.

But with fuller knowledge of the forms and life of species, and with more species and varieties too, this conception became a relative one; as for Buffon: and thus, and thereafter increasingly, an evolutionary one accordingly, in which each and all the forms of life independently develop, each in its own system of reference throughout space, in time as well, and throughout its varied movement of functioning. This, in fact, can be traced into and throughout the sub-sciences of biology, i.e. in life's varied forms and functionings, their different appearances in time, their very various distribution in space, and combined in their development and racial evolution accordingly. Here, then, instead of seeing any serious transformation in biology arising from this new mathematico-physical revolution, from Newtonian absolutism to Einsteinian relativity, we can but congratulate its exponents on effecting this needed emancipation; albeit with some mild surprise that this should have taken them well on for two centuries longer than for the analogous progress from Linnæus, as absolute creationist, to Buffon, as evolutionary relativist, since these were practically contemporaries.

RELATIVITY IN SOCIOLOGY.—The like, too, for the social sciences. In Newton's day (as for "fundamentalists" still) there prevailed

the unquestioned conception of the single creation of a human pair, thus of common ancestry with "the chosen people" of old; and since then with a single main line of continuity of civilisation (taken as essentially Mediterranean, or thence Nordic, and each self-chosen in turn). But these doctrines have given place to the tracing of (various?) long descents from allied animal forms; and in any case to an evolution of very different peoples in different places, at different rates, and in different times; so with different systems of reference. Hence our eventful European calendar has as yet no value for the Australian, so far as still paleolithic; though his long-persisting time period has prehistoric interest for us. Is not all this Relativity? i.e. on the social level; yet truly comparable to mathematico-physical relativity, since also of time, space, and movement, in differing reference-systems, throughout organic and human life, as now seen for inorganic nature. And the question even rises—has not this Relativity doctrine thus originated, however sub-consciously?

In all essential ways, then, the sciences of organic and social life--albeit less rigorously precise, since more intricately variable, than those of the inorganic world—have been earlier, and even more fully, relativistic. Or is it perhaps even because of these difficulties and limitations of the sciences of life? And do not all sciences arise from Life—life social, not simply organic.

Hence without losing sight of the fundamental succession, in the upbuilding of the sciences, from mathematical and physical knowledge onwards, we plead for fuller co-operations, beyond the present too specialised detachment of science from science. It is to the mathematical mind that we owe the origin and progress of our graphs, throughout all the sciences; as from the simplest co-ordinates onwards; as, of course, also our statistics, from simplest numeration onwards to their mathematical elaboration. Hence it is a little surprising (1) that the eight sub-sciences of biology should have arisen empirically, without mathematical aid; and (2) that it seems left to us as biologists—seeking thus to arrange our innumerable facts, to submit to the experts what appears to us the mathematical reason, and even necessity, of such an eightfold presentment; since grounded in space, movement and time, and this throughout the physical, the organic and the social sciences alike. Yet does it not show too how mathematician and biologist are more akin than they seem; since to his counting, measuring and reasoning we supply not only a wealth of phenomena to be thus treated, but these so far rationally classified as well? It is surely through the unison of both concrete presentment and abstract reason that science advances; but mathematicians have less monopoly of the latter than we are wont modestly to think; for, after all, the "logy" of each science is *logos*.

Yet as of these eight sub-sciences the first four are static, morphological, and non-living, in the four fields of life in its functioning we need a further notation for the life-process itself, i.e. for ecology and racial evolution, for physiology and individual development; and besides these, for their analogues among the social sub-sciences. Finally, one other point. If our outline-notation proposed for these life-processes be found rational and applicable, may it not even be found suggestive towards such "organismal" treatment in strictly mathematico-physical problems as Whitehead and others are on the way to? An attempt towards this therefore concludes our notational chapter; for, after all, each and every science has arisen in and from social life with its human needs; and so still may profit by that general point of view, as well as advance upon its own specialised ones.

CHAPTER XIII

TOWARDS A THEORY OF LIFE

A. INTRODUCTION AND PRELIMINARIES

REGIONAL SURVEY, NATURALISTIC AND HUMAN.—In our long series of summer schools at Edinburgh, with which began many years ago that movement now widely developed in Britain and in many countries of Europe, we started from the first with the association of biological with social studies, and these alike on their direct observational bases, from nature in country-side and sea-shore to botanic and zoological gardens, museums, etc. And similarly in everyday life in country and town; so from its simplest occupations in hamlet and village to the elaborations of industry and commerce, and the further development of culture in great cities. In such surveys, year by year, we came to have the collaboration of eminent geographers, both naturalistic and social; so with the geologist, the oceanographer and meteorologist, of ecological and other botanists and zoologists; and similarly from the anthropologist, the antiquarian and the historian, to the social economist, the hygienist and physician, the educationist and cleric, the magistrate and administrator, and sometimes even the philosopher, the moralist, and the student of comparative religion. In course of these surveys arose our beginning of a school of nature-study and sociology in the Outlook Tower, with its many studious (and even practical) interests, ranging from its immediate outlook over Nature, City, and Region, and below these, storey by storey, to Scotland, British Isles and the English-speaking world; and thence again to an outline of Western history and civilisation, and their current events. Beyond these to the East, and finally towards humanity; from simplest origins, to civilisation in progress towards its various aims and ideals. Yet all alike environed and conditioned by Nature, and more or less re-conditioning it. Such an outline, far from being in any respect complete, is none the less an indication of an attitude in thought and life, and in education uniting these, which seeks to combine the specialised advances of the science. And this at once in their naturalistic, their systematic and evolutionary treatment, so appealing at once to the amateur and to the specialist and even from the children of the schools, the passing tourists, to the meditative student of life and the critic of society. Geography and Philosophy are thus (in principle, however imperfectly in detail) unified as Geosophy; and Biology taken at its widest, and

with Psychology, thus becomes seen as a Biosophy in the making. Here, then, is an endeavour towards the enrichment of our simple everyday thought-world of place, work, and people—people, work and place; in which we are all involved throughout life—and indeed as ordinary life. Even when we withdraw from this, to think in solitude, such outline-synthesis is of service, and towards steps further.

The regional botanic surveys, as of Languedoc under Flahault, and of the late Robert Smith and Dr. Marcel Hardy, extending from Dundee, have given impulse to the widened and intensified surveys of the Ecological Society. In fact, this Survey method, rising as it does from observed details to their interpretation, has long been increasing in extension and in refinement, so that schools of geography, as at Oxford, etc., and of sociology, as at Le Play House, etc., have increasingly been applying and advancing it; and it has long been arising in Training Colleges, especially the more progressive feminine ones. It aims, too, at covering regions and reaching their cities, as notably by means of their museums, already frequently becoming civic and regional. Thus a recent temporary social exhibition, of "Place, Work, and Folk" at Aberdeen afforded so successful a co-operation of naturalistic and social interest, as to justify organisation towards a comprehensive and permanent one. Kindred beginnings, even further advanced, are widely in progress, much as with public libraries in the past generation and before.

To make this needed intimate association of nature-study and social survey yet more clear and concrete, it is here worth while to recall an actual programme, carried out some good few years ago in the first of such summer schools in India; and realised co-operatively, and to the satisfaction of its students, by means of morning lectures and frequent outings devoted to the understanding of the town and its neighbouring villages, etc., and with afternoon lectures and excursions in Nature. The place was the sublimely situated and locally and racially interesting town and neighbourhood of Darjeeling—that Tibetan frontier district into which Dr. Hooker ventured on his productive and famous Rhodendron quest of well-nigh a century ago. His arrest, for trespass within that land so jealously interdicted to foreigners, helped notably towards its annexation; and it has since been the "Hill-Station" of Bengal; famed for its mountain-landscape, the finest in India or perhaps the world; and important also for its tea-plantations.

This parallelism of biological and social studies will be seen as obviously applicable, day by day, at any point where nature and social life are alike easily accessible, though from great cities whole excursion days are needed for nature and village survey. After such twofold survey, the kindred ideas of biology and social science are readily realised; and as valid generalisations, cleared henceforth of

the mere abstractions which have too long impeded the rise of these. Moreover, beyond these intellectual results, there soon appear corresponding practical ones, and these from both lines of survey. Thus our Nature-survey is obviously suggestive towards land reclamations, as to forestry, to pasturage improvement, and to agriculture at its various levels; from poorest croft to richer farm, to garden and orchard, and with irrigation or drainage as the case may be. And similarly for the improvement of the village, town, and city, as every hygienist, town-planner, and improver more or less by this time knows; and as, for more directly human efforts, all manner of social workers are also increasingly finding. In short, then, our bio-social survey methods are thus rising towards educational progress, and even social statesmanship. For the task of this is becoming increasingly extended, beyond taxation, justice, defence, etc., to reconstructive and geotechnic measures, of which the barrages of Nile and Indus, the reclamation of the Zuyder Zee, etc., are salient examples; and the re-sanitation of Bengal and Ceylon, the renewal of Mesopotamia, etc., are approaching ones. For our present purpose, however, the reprinting here of this syllabus is first of all to justify the association of biological and social studies, and to suggest its trial, and with improvements which may readily suggest themselves; and next to serve as introduction towards a further attempt at this, even to graphic precision, and incentive to research.

Various results are thus reached in such Summer Schools of Survey. The first and most appropriate, we repeat, is that of attention to the immediate environment, by the Survey of the Region, in its many aspects—from its natural beauty and sublimity, its geography, geology, and meteorology, its botany and zoology, its forestry and agriculture, and to its anthropology and village life, its modern town life and problems also. In observations of all these, with their interpretations as far as may be, interest develops, in natural and in social sciences alike, and in bringing together their essential points of view. The saying, "Many men, many minds", is in this way illustrated; yet, in course of such a comprehensive survey, main streams of thought and tendency appear. The modern conflict of ideas becomes more intelligible; and the co-operation of good wills more hopeful. Such needed Survey is thus not merely of the town and neighbourhood before us. It is also a far more general stocktaking; even to that of the ideas and ideals now in conflict and in transition over the world. Among these what can we select, and what best apply in the opening future, in the East and in the West?

The following syllabus indicates the general treatment of our two main courses, respectively introducing to Sociology and Civics, Biology and Bio-technics, yet these in close association, and even

daily parallelism. In this actual harmony of studies will be seen to lie a three-fold thesis, for East and West alike: (1) That the needed renewal—of Education—with reunion of its dispersed endeavours towards reorganisation of its deteriorated or insufficient methods—lies primarily in and through a corresponding renewal of social feeling, and thus towards Citizenship; in which (2) the economic, political, and other divergences and conflicts of the present may be progressively harmonised. (3) All studies and surveys, whether naturalistic or humanistic, thus lead to Social Service; and realise themselves in this; while each and every Service requires active and continued Survey, to make it adequate, and keep it effective; much as in war. Action and Thought, City and University, thus progressively interact; in and towards fuller Life—that of Society and its Members, mutually advancing in their evolution; whence Achievement twofold, both naturalistic and social. Civilisation and Nature are thus unified, within the concept of Life in Evolution; and of this as advancing, day by day, through labour and experience, guided by design, and realised in deed. How then are we to justify this large programme, and its ambitious forecast of policy? First concretely, in survey, and thereafter more interpretatively. Here, then, in striking parallelism, are our concrete surveys, each with beginnings of interpretation too.

RUSTIC AND URBAN THOUGHT.—Returning, however, from such resulting close parallelism of these Surveys in themselves, one notable result is to clear up the distinctiveness of rural and urban thought, and their respective significance. Nothing has been more characteristic of the development and expansion of our industrial age, with its commercial, financial, political, and military developments, than the predominance of the life and thought of great cities over those of the rural world; indeed so far that the urban mind often wonders if the rural world can be credited with any mind to speak of. How, indeed, should a man who has spent the time of his mental development amidst the woods and fields, and dealing with living, growing objects, subject to laws he but vaguely discerns, and over which he has too little control, look at the world in the same light as one who has passed his days in the city, where the movements he sees are mostly those of mechanism, and the objects on and with which he works and comes in contact are inanimate, and much more directly under control. Yet in his slow way the rustic, quietly watching his crops grow, is more of a biologist, and even of a philosopher, than he knows; and in his work he is far more versatile, and thus more widely experienced, than the townsman. For the old English labourer and his fellows over the world have ever been masters of many different difficult tasks; hence the one real boast we remember of our late friend,

President Stanley Hall, of well earned educational and psychological fame, was that he was glad and proud to have practised, in his boyhood and adolescence, on his father's New England farm and village, as many as seventy occupations, nowadays mostly taken over by wellnigh as many townsfolk; and thus he had what he rightly regarded his fundamental education for life, and even for thought as well. The explanation of the general fact of the large indebtedness of the European city to its rural immigrants is thus not far to seek: nor even the still greater predominance of these in the American *Who's Who*?

The rural upbringing gives more than health and vigour; for its immigrant youth awaken to the stimulus of the city, with a freshness beyond that of town youth to which it is so habitual; whence often doubled powers. And as every society has much of coherence,

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SOCIAL STUDIES

I—Village Study

1. The Region and its Outlooks,
2. Excursion,
3. The Region and its Occupations,
4. The Village (*a*) in Developments, (*b*) in Deteriorations,
5. From Village to Town,
6. Village Survey (Excursion).

II—Town Study; and Treatment

7. Town Survey (Excursion),
8. Problems of the Town,
9. Possibilities of the Town,
10. Indian Towns and Town Planning,
11. Great Cities of India.
12. Home, Village, Town, and City (Excursion).

III—Cities in Change; and Ideas in Conflict

13. "Western Civilisation" as Industrial Age; its main Ideas,
14. Critical and Revolutionary Movements,
15. Solutions in Progress,
16. The War as a Conflict of Ideas,
17. Reconstruction after War (Regions, Cities, and Universities and Schools, etc.),
18. Excursion and Discussion.

IV—Social Ideals, in Evolution

19. Exhibition of Ideas,
20. The Contemporary Transition,
21. Through Determinism to Freedom,
22. The City's Evils and Burdens,
23. Possibilities of City and Citizen,
24. Excursion and Discussion.

newcomers find it hard to enter its average mass: hence have often to begin at lowest; yet with fresh mind and powers, of active efficiency, they even rise to the top. Urban youth, even when not deteriorated to townling, is seldom fitted for undertaking country labours, even were these easily to be found; hence seldom before age and prosperous retirement does the townsman settle in the country at all; yet then with higher status than its average; in fact, so much so as often to afford a main inducement tempting him there. Thus, at best, may come improvement of rural work and conditions. In such interchanges the co-operation of rural and urban life and thought become clear; and the advancement of this at its best, the abatement of it at its worst, is thus a main problem of contemporary life and civilisation.

Though the lot of the peasant, in not a few past historic periods,

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NATURE STUDIES

I—Nature Study

1. Nature Study and its Outlooks.
2. Excursion,
3. The Web of Nature,
4. Nature in Contrasted Aspects,
5. Nature in Growth and Integration,
6. Nature Survey (Excursion).

II—Life Study, and Treatment

7. Ecological Survey (Excursion).
8. The Unity of Life,
9. Experimental Control of Life,
10. The Life in Tanks,
11. Agriculture in India,
12. Forestry and its Significance (Excursion).

III—Life in Change; and Theories of Evolution

13. Darwinism and Post-Darwinian Theories,
14. Theories of Sex and Variation,
15. Nature as Protean and Progressive,
16. Death and Life in Conflict in Science,
17. Nature-Resources and their Control (Material and Educational),
18. Excursion and Discussion.

IV—Ideals of Life, in Evolution

19. The Curve of Life,
20. Through Mechanism to Vitalism,
21. Education as Psycho-organic and Psycho-social,
22. Life's Evils, Diseases, and Burdens,
23. Possibilities of Individual and Family Development,
24. Excursion and Discussion.

has often been far from an enviable or esteemed one, and his condition now is by no means so bad as it too often has been, the urban low estimate of his intelligence seems to have reached its climax in our own day. Witness not simply the popular cockney estimate of "Hodge"—and there are cockneys in every city—but even the extreme one—of that would-be most democratic and certainly most proletarian of all influential writers, Karl Marx, for whom the peasant "incarnates barbarism in modern society." And it is manifest in Russia that this view has been maintained in its proletarian doctrine and regime. For in our industrial age, physical sciences and machine processes have educative value so far as they go, while to this peasants largely remain ignorant, if not refractory. Yet though the townsman can thus so far justify his superiority, he, in his turn, is seldom less ignorant of the peasant's world, of life and growth, and no less refractory to them; since usually confined to the circle of ideas which his leaders in industry, commerce, and finance commonly possess; or easily satisfied with the well-expressed abstractions of his political, legal, economic, and other leaders—when not, as often most of all, preferring the leisure and pleasures of his city; and these also increasingly attract the young rustic to come to town. Again, the educated and thinking townsmen are many, in comparison with those of the rural world; and its thought has been, and still too commonly is, left out, between that of physical science and its applications on the one hand, and that of the traditional "humanities" on the other. So, when the thinking rustics, like even Darwin and Wallace, bring their ideas to town, the townsfolk first doubt their vital contribution to science, and next reduce it to terms of their own competitive system. That typical Jura-peasant-thinker, Pasteur, had a hard task to teach what he had learned from tan-yard and cottage, with his cleaning of its milk and bread, its wine and beer, its flesh-food, and so on, even to his abating of the rural tragedy of the mad dog; and he could only do all this effectively from his city vantage-point; there taken simply for chemist, instead of the profound unraveller of life's secrets that he was. His greatest disciple, Lister, albeit fundamentally a good "Shepherd, with the tar-box by his side", needed also to be surgeon and professor in the city—that is, barber, and up to the record "clean shave"—to gain slow and often reluctant acceptance, even from his profession. Here, however, such examples illustrate that full and fertile combination and interaction of the urban with the rural thought, which is, of course, the ideal: what we complain of is that in its general thinking, the urban world remains still too little affected by the rural. Hence that claim for our studies of life, and this in its widest senses, organic and psychologic, social and ethical, which more or less runs through this volume—happily also through many others, yet not enough—that

it is for those biological and evolutionary sciences to claim nothing less than central place, even in urban thought and education, and in applications as well. Why so? Because on one side the physical sciences and their applications can but deal with the environment of life, and thus with its underlying conditions and applications; while, on the other side the whole range and heritage of thought of "the humanities", and their entire range of applications to human affairs as well, are no longer to be taken as commonly taught and known, but as offering so many fields of re-investigation, and where need be re-adjustment; and this in terms of Life, in its history and evolution. Such re-interpretative science of life, human and organic, with its re-sanitating and rejuvenating arts, is thus still but at the outset of its career; yet towards changes greater than most, if not all, of those of recorded history to which importance has been rightly given; so perhaps not since the rise of neolithic agriculture and its life-advancing labours, in place of the long dominant palæolithic hunters. For recorded history, with its three thousand wars, is fundamentally of so many interactions of this unextinguished and ever-recurrent hunting civilisation, in its many influences and developments, with the rural life. If so, why is this relatively so mute and unhistoric? Memory vividly retains dramatic and tragic evils, but can keep little or no chronicle of the quiet and uneventful rural life and labour; for which crops, stock, and children have been and remain of essential interest and concern; and even their defence is a secondary and too often far from successful one. But now it begins to be recognised anew that health and fundamental weal are alike on rural basis, with the need that the town be rejuvenated on rural lines; hence the Rural Renascence cannot but follow. It is even now doing so; though still conspicuously in but few points, as in Denmark and Ireland yesterday, but surely more widely to-morrow. Such a generalisation as that urged by any brief anthropologic retrospect, the usually prehistoric origins of all our cultivated plants, and all our domesticated animals, and with domestication and cultivation of man accordingly, gives conspicuous evidence of biological and even evolutionary technique in the remote past; and after the long (and largely vitiated) ages of recorded history, we are now beginning to recover this, with ever-increasing advantages accordingly. With eugenics reconciled with euthenics—nature with nurture, good breeding with good rearing and right living—we begin to see again new hope for humanity, towards renewing its individual development and social evolution, and in fruitful interaction.

Our claim for rural and vital thought and action is thus a very comprehensive one. One to which the mostly urban revolutions—of the historic past and recent present, or threatened future—are, after all, of minor significance; since nothing less than a claim to

subordinate all the reddened banners of international and civil wars alike, by the green; that of our rural and evolutionary thought and action, leading towards vital re-education, and reconstructive Peace.

This main difference cannot be too clearly defined. Briefly stated, it is that the urban thought of science and its applications is essentially in terms of physical sciences and their related crafts and arts; so that even hygienic endeavour is but recent, and still far too little realised; while the physician is but consulted in need, without understanding of his biological point of view; and such evolutionary thought as there is tends to be perverted, in terms of competition, if not even war. Though thinking rustic minds are still far fewer than those of the urban occupations and their appropriate sciences, and their thought utilises all it can of these, their essential interest turns towards life organic, psychic, and social, and to the tending and enhancement of *these*. Hence then the need so often urged in this book, of this vital outlook, and its critical and constructive application, through the whole urban culture, both general and academic, reconciling both its mechanistic and its humanistic studies and activities by absorbing and re-stating them all in terms of its essential concept of Life in Evolution. Undoubtedly a large demand, and which we can but leave for fuller exposition in our sociological papers; yet one which we would fain stir our biologically-minded readers to share, and state in their own way.

BIOLOGICAL INTERESTS AS ARISING FROM SOCIAL. —How comes it that our parallelised outline of biological and social surveys shows them so fundamentally akin? Anatomy and Physiology were human, long before they became comparative; and the ethnographic classification of human races (Shem, Ham, and Japheth) long antedates animal and plant classifications. The idea of Palæontology arose from archæology, after this had been pushed to "giants' bones" and "pilgrims' shells". Embryology arose from the questions arising before human birth, and Evolution largely from eighteenth-century "progress"; and so on. So in many or all respects it has been natural, simple, and profitable for man to begin his biology with man, as did the naturalistic physicians; and human economics, and even politics, generated Ecology too. For its playful founders, the old fabulists, knew kings before they told them tales of the king of beasts and his difficulties among and with his subjects; and Solomon too was king before he counselled to "*go to the ant*", or discoursed of the plant world from the hyssop to the cedar. Most of all is this order of treatment convenient for that general Theory of Life which it is now full time to outline: since "Place, Work, and People" are obviously far earlier and simpler conceptions, for race

and individual, than are their modern biological parallels of "Environment, Function, and Organism", which are so generalised as to seem comparatively abstract. So after manifold trials, and of both methods, we begin this outline of Life-theory by starting it in the simple old human way; yet which soon leads us into the animal world, and its ways of life.

CONDITIONS OF FURTHER STUDY.—In thinking of place, work, and folk, we, of course, know our own circumstances best: as in geography, general and local; in such occupations as we may be most familiar with; and such people as we have lived with or met; and thus to recall our essential life-experience is a very useful beginning. But we soon find that our experience has been too varied and complex to set down simply; it would lead us into a whole autobiography; and such records, however interesting, do not furnish what we seek, a measure of the process of social life, in parallelism to that of organic life. Moreover, these are nowadays more separate than of old; so it is among simpler folk than ourselves, nearer Nature, and in close touch with her, that we must begin. Man, in Nature, can only conquer her by first obeying her; by seeing and taking what in that place she gives, and thereafter observing and searching out what more he may be able to obtain from her. And this at first, and always fundamentally, by direct labour, to the sweat of his brow. Such simple folk were thus in the country long before there were towns, in caverns or in huts before they built houses, and living by gathering, fishing, and hunting, before they had domesticated animals for pasture, or begun cultivation. Even at his most civilised in later periods, until to-day, man but slowly develops from such simple conditions; and since we find survivals of these early phases to this day in many parts of the world, it is evident that our study of human life, in various places, at various work, and of such different peoples, must be sufficiently broad and comprehensive to include them all, and apply to the prehistory, and next even the history, of all peoples, to our own days and ways.

This is no doubt a very large and serious change from the personal and autobiographic way from which we started—in fact, its very contrast, that of looking at life no longer from the personal standpoint, but the varied yet universal one of humanity, throughout its varied peoples, ways, and places. Yet the most self-concentrated individual has some notions towards this; as from his very street; and from the country around his town, let alone from newspaper and map, from simplest history school-book to varied library; and which his further life-experience and holiday travel are ever extending. The aim of the nature-studies and regional surveys above sketched is to bring this widening experience and understanding into education in its largest sense, for all phases of our lives.

This seems a large demand upon each busy life; but, after all, every tourist, every reader, worth the name, is so far on the way to meet it. Summer schools here find their further attractions and uses, like the one of which the course is outlined above.

A CONDENSED SURVEY OF PRE-HISTORY AND HISTORY.—Yet most accessible, comprehensive, and rapid of all these initiations so far, into the actual beginnings of our human world of place, work, and people, and with much of history and nature-study as well, are our vacation-courses in Dordogne, here worth recalling. On the map of France, look some sixty miles east from Bordeaux to the union of the Vézere and Dordogne rivers. Everyone has the idea of a river-course with its valley-slopes, and these generally gentle in the lower course, yet further up often steep, even to precipitous. But the Vézere, thanks to the character of the rocks along its course, has done wonders, beyond any other valley we have seen or easily can find the like of; by under-cutting its precipices, so far as to yield characteristic ranges of shelter ("abris sous roche"), under high cliffs, overhanging so far that at the village of Les Eyzies, for instance, no drop of rain falls on the range of small houses below, or even on the larger chateau beside them. Moreover, these cliffs have many caverns, often reaching far back into the darkness, so the early shelter of wild beasts, until early man found ways and means of expelling them and taking their place. But caverns, although easily defended by their occupants, are damp, and rheumatic accordingly, not to speak of dirt and its diseases; so at Les Eyzies especially the long ranges of rock-shelters outside them afforded the means of building dry huts outside the caverns. Hence to this day there are some ten thousand of such dwellings in France, particularly in the large region of which Dordogne in general and Les Eyzies in particular are richest in caverns; so that from what seems an ordinary small cottage, the living-room back-door opens into the cavern mouth, through which we can peer into the darkness, or explore it with its owner for guide; so learning that prehistoric and contemporary life are here amazingly continuous. Here then is one of the very best and fullest of pilgrimage and exploration centres for prehistoric archæology, for in a single section of a cavern-bed, one may see also its ideal museum, unarranged by human hand, but simple cut bare. For there at bottom the lowest gravel-layer shows no sign of human or animal life, but immediately above this one sees here and there a flint too rough for positive certainty as an implement, yet possibly an eolith used by man at his rudest, before he had reached skill to shape it. Above this, however, another layer, with rude but unmistakable palæolithic implements left projecting from them; and so on above these, in layer after layer, the more developed and now characteristic implements

of successive types of palæolithic and neolithic peoples, while at highest level projects an implement of bronze. Bones of animals which these peoples had hunted and captured, and these from denizens of climates now as far distant as chilly Lapland, with its reindeer, or Africa with its rhinoceros. We thus see the succession of glacial periods, first compelling the cave-dwellers to burn fires against the cold, and then, with rising rivers, driving them out altogether; until with a return of better climate came a fresh and distinct type to occupy anew. In such ways, and in a few days spent between well-guided cavern visits and museum studies, reinforced by books of reference, and sometimes vivified by actual dramatisations of the past, the novice to these studies sees the way towards becoming an initiate. Of course, something of the like can be done, though generally on smaller scale, at any of the kindred caverns in our own island or elsewhere. Leaving now the Vézere valley, for the more ordinary but still varied and beautiful one of the Dordogne river, one can next survey and vividly realise, with help of correspondingly skilled geographic and historic guidance, much of recorded history, from remains, and monuments along its course, from Pre-Roman Gaul to Roman, and thence through something of the "dark ages", to fully developed feudal and catholic times, and thence onwards to and through those of the Renaissance, and its decline, to the mingled developments of our own day; or again, in the range of interesting little old towns, find survivals of past ages below the day's adornment by the billsticker. Thus a broad survey—of the varying adjustments of people and their doings to their place, throughout untold ages of pre-history, and then two thousand years or more of history—is condensed in a brief fortnight of experience; and so with training towards better use and more result from all subsequent travel, than that of conventional tourists, unaccustomed to observe, to reflect, and to image.

Similarly to start towards fuller appreciation of nature, even a single walk with the geologist or with the ornithologist or entomologist, may often be a revelation and an arousal; or again, the cloud-landscape, as seen by the meteorologist, and by the painter. It is indeed largely by help of such vivid experiences that bright adolescence, sometimes even childhood, is often awakened to some new interest, and this even continuing and extending through life. A peep through microscope or telescope can often work the same magic, and so on; so in whatever living way we may directly enter this scene or that, of nature or of civilisation, a complex and ever interacting drama of evolution opens before us.

THE VALLEY SECTION.—But how are we to elucidate and develop, from all this, the general conception of social life? As interaction of people, work, and place, and in keeping with its

biological terms, of organism interacting with environment. It is simplest and most convenient to begin with the environment; and for this one needs a convenient survey, with space enough to be a true world sample; yet not too large for convenient survey. Here then the world's relief gives the clue; especially for our western Europe, with its many river valleys, and plains not too large for ordinary limited vacation experience. Witness, for instance, if we review the east coast of Britain southwards, the Dee, the Tay, the Forth, each ranging from mountains and foot-hills to more of fertile plain; and so for Tweed and Tyne, and southwards to the Thames. As we come southwards, the proportion of hill country diminishes, that of plain increases, so with corresponding occupational and social change as well, as from hunting, pastoral, and poor crofting regions to more and more preponderance of farming. With such notion of regions in their solid relief once clearly obtained, our valley section develops to island section, and this again into the wider world; so thus a simple standard diagram is arising in our minds, readily adaptable in detail to each region, be this great or small.

Given then this broad outline, its adaptation to each river valley —above named or no, and smaller or greater than these—is an easy matter; more of mountains and hills for Dee and less for Tay, less still for Thames, so more of gently sloping plain in that. So next this section is of Scotland, from West to East, yet readily adaptable to Wales and England, to Norway and Sweden; and so from Switzerland down the Rhone to Marseilles, or across Italy. The like further afield; say from short Greek valleys to the long ones of Nile and Euphrates, of Indus, or Ganges, or Yang-tse-Kiang, or across America; again mostly from short valleys towards West and longer towards towards south like the Mississippi, or east for the Amazon. For broad visualisation of the great world, in its relief and its place-units, our suggested diagram is the simplest and clearest possible beginning; although, so far as geographers, we need next to develop all these, as did Reclus in his *Geographie Universelle* and towards his long dreamed "Great Globe", that colossal model in true relief, once and again on the way to be realised, as it will be some day, since needed complement to Zeiss's planetarium.

Our simple outline section next, of course, needs geologic development, but here again something of local knowledge is not hard to find, nor to enrich with some notion of mineral products, as from flints to ores, even to jewels or gold, yet now, above all, of soils, from intractable to most cultivable. Similarly, a natural vegetation picture is indispensable, for which ecological maps are becoming finished enough to help us; yet, broadly, they are all variants of Humboldt's first diagrams; since downwards from snowy heights, though lichens and mosses with struggling herbaceous plants of

many kinds, from poorest grasses and sedges in wet places to brilliant flowers, as so many have seen in a Swiss valley in spring and early summer. So also the succession of trees of the woodman; from struggling birches, down to the "Black Forest" of Conifers, and thence to the "good greenwood" of deciduous trees. We note the spaces of pasture; from narrowest footholds for the chamois, to rich alp-pasture slopes for cows; or, as in Scotland, through moorland pastures giving but scantier sustenance to fewer hill sheep. Then slopes just reclaimable for poorest crofters, and at length below to the good deep soils, with their varied natural flora, left only in corners by the farmer. The forests have largely been destroyed by man, from Scotland to the Mediterranean, and Spain to Syria; yet on the poorer soils especially we yet find survivals, as at Epping or Fontainebleau. As we descend along our section, we find, in more sun-favoured lands than our own, the vine upon the sunward slopes; and next, as we reach the Mediterranean region, the olive appears, and this as most indispensable of factors for that region's historic civilisation; so that no development of work and people, even up to peace and wisdom, to arts and learning, to literature and mythopoesy has been more clear than with the olive. Yet grass and corn and vine have each such interesting relations. Indeed, all else in man's working associations, with plants, and with animals too, have each their characteristic occupational and social effects, their distinctive civilisation-values; as witness, for vivid instance, the old and wide respect for bread and wine, and raised to highest sacredness for Christianity.

THE FUNDAMENTAL OCCUPATIONS.—Our valley section has thus passed beyond our naturalistic outline, since man's occupational association with it throughout his history has been an increasing one, and by turns for good and ill. In fact, it is hard to find "Nature", untouched by man, between mountain-snows and sea-shores, since our own wild and unused moorlands and barren hill-sides, or the vast Mediterranean heath-lands, from Spain to Syria and beyond, have been disforested by human agency; where their soil, with that of much of long-cultivated areas as well, has been washed down into the plains or the sea below; at best, with more or less of delta formation accordingly, and this of all degrees of fertility, from richest, for Nile, to poorest, for Rhone.

Thus our valley-section, broadly outlined for Nature, admits of similar outlines for occupations; since in the forest man must hunt or starve, on the pasture graze his flock or starve, and on the plain plough or starve; and by the sea, fish or starve. From the prehistoric invention of cookery, the woodman appears; and beyond picking up flints, these were seen to be worth mining for; and in time the like for the copper and tin of the bronze-age, and then

the iron. Conveniently then we may group the fundamental human occupations along the valley section, with miner, woodman, hunter, shepherd; and then cultivators, in their three forms of agricultural development; from the hard upward reclamation by the crofter, down to the finer development of gardener and fruit-grower; and there seems little doubt that it was by the extension of woman's hut-side garden-beginnings that our farming of fields began. Space does not here allow any tracing of the development of the hunter's solitary hut, the pastoral camp, the crofters' hamlet, the poorer peasants' village, and the prosperous farmers' cross-road market-town; still less of the great cities, so often ports. But their mingled homely and marketing origins are clear; and next the tracing of all the many occupations in the modern census, as developments, differentiations, and varied combinations of these few main and well-nigh fundamental ones, beyond the primitive simplicity, of mere gathering, hunting, and fishing. Here then are place, work, and people, in simplest outlines; from which have arisen the division of intellectual labour of geographer, economist, and anthropologist respectively, with their distinct learned societies, their university departments too. That all this can and does greatly advance these sciences, beyond this first geographico-economico-social outline, is obvious and unmistakable; with the sheer multiplicity of observations in every field, this division naturally continues. Yet, alas, it has come to division so extreme that their three Societies are scattered in different parts of their city, and have but few members in common between any two of them, and hardly ever, if at all, in all three: while similarly in the University, their departments, professors, and students have too commonly no co-operation of studies worth speaking of.

SOCIAL ECONOMY.—Yet this is but a phase of the modern division of labour, and shows signs of change. Thus economics increasingly takes note of geography; and each comes into touch with the historian; as he with pre-historian increasingly too, and the latter with the modern anthropologist. Yet all these beginnings of co-operation have mostly arisen within recent memory, and are still far too incomplete; so the practical question arises, can we not advance it further; and even rapidly and effectively?—since only by synthesis of all these studies can any living understanding of human life in its evolution be obtained. Here, at length, is where our bio-social parallelism claims fully to come in. We do not need to wait until the remote Kalends when the geographical, economic, and anthropological societies have finished their three main lines of inquiry, each sub-specialised more and more finely. For us as biologists, the synthesis is not remote at all; for its principle is in our hands from the beginning, viz. that organism acts and reacts

on environment; that is to say, in human terms, folk act and react with their place. The life-process then, in principle, as Herbert Spencer and others long ago have seen, is like the reflex action, in which environmental stimulus evokes response; and this normally with some effect on environment in turn, as our being in life is readily recognised by our breathing; in which each inspiration from our air environment is at once maintaining our tissue-life yet so far also burning it away; and each expiration being that of a now modified atmospheric content, poorer in oxygen, richer in carbon dioxide and water-vapour; much as with a cooking-fire or a blast-furnace. So in the world of social life is stimulus and response; as from fruit we pull, from stone we grip, and shell we break, to modern elaborations of technology. And as "the dyer's hand is subdued to what he works in", so for every simpler or more developed occupation, and this for family too, woman and child as well as man; for as the hunter must have hands free to shoot and limbs free to run, the squaw carries the burden. Their hard (and most readily warlike) life is comparatively short; but with flocks to herd and milk, and wool to spin and weave, the long-lived, leisured, and often truly cultured pastoral family arises; and its caravan developments as well. The poor peasant has a strenuous life, and his wife with him; whence economy, even to her filling "le bas long", which is the appropriate French popular name for the Bank of France, as "the old lady of Threadneedle Street" for the Bank of England. In more prosperous agriculture, the best farmers, as Le Play told his students long ago, are essentially "those that have the best wives". In the sea-fishing life, the fish-wife not only baits the line, but takes the fish to homes or market; whence an historic and cumulative factor—more important than either feminists or their critics have noticed, or may admit—of the active origin, and earliest success, of the political claims of women in the maritime countries, towns, and cities of Western Europe. Turning now to custom and law, we see the varied conditions of land-tenure fundamentally explained by the peasant's division of land among his sons; while Norman inheritance by primogeniture is not a little explained from the necessary maritime hierarchy of father and sons, in their order of age and experience, and with indivisibility of the boat, and its authority alike, for which the eldest son—as "first mate" of most experience—is normally the best fitted. And so again, for the great difference of Western law, as individualistic, from that of Hindus and Chinese as more collective, with much of family ownership. These are respectively determined by the staple cultures, of wheat and rice respectively; the first, with ploughing, etc., so essentially individual, the other so fully communitary, since from general water-supplies to planting and harvesting. So again as to the long terms of imprisonment for crime, so long characteristic of Mediter-

ranean law and its northward outcomes; we can but smile at their conventional explanations in the law-books; for when we translate penal servitude into French—"aux galères"—we have at once the fundamental explanation, in Phœnician and later navigation, by oared galleys; hence with urgent need of capturing and condemning sturdy fellows, as slaves to pull them.

Enough however of such illustrations from social science and social economy; if, whether accepted in all respects or no, their point of principle be seen; viz. that place, work, and people are ever interacting and thus evolving all manner of outcomes. If so, it rigorously follows that our separation of physical, biological, and social science is but a convenient division of labour, towards keener analysis of each; and that these find their synthesis in Life's process—the fundamentally physical place, the bio-functional work, and the social folk. And the same for geography, economics and anthropology within the social field.

RESULTING CLAIMS FOR BIO-SOCIAL SYNTHESIS.—So unless this whole long argument be demolished, it must be faced; for obviously neither ignorance of it, indifference to it, much less practical conspiracy of silence, can fairly prevent the critical consideration it demands. With all due respect for the subdivision and specialisation of the sciences, this after all is but a necessary and important process-phase in civilisation, that of the industrial age especially. And while few can have worked longer than have we among various of their specialisms, and at their classification also, we have thereby come all the more increasingly and clearly to see that this synthesis is a matter not merely or mainly of our academic logic; it is of the very nature and functioning of Life, organic and human; since in continual play of interaction, between organism and environment, and people with place. But if so, all these separations of Life-science into sciences, sub-sciences, and specialisms within these have been but the setting up of the warp-threads of thought, through the whole of which life is ever throwing its all-unifying shuttle. Philosophy has long claimed to unify our knowledge of all kinds, and to discern and assign to these their respective values; and in this task its varied viewpoints, reasonings, and doctrines are of manifold interest and value. Yet, just as definitely as with all and due respect to the elder and pre-evolutionary naturalists, and with incorporation of their labours and discoveries, we yet locate and estimate these in the measure of their understanding of life, in a word, their contribution to Biology; so we cannot but do for the philosophers; as indeed for scientific workers too. Using Biology in its most comprehensive sense, the physical sciences search into our environment; and thence more and more control of its energies and resources. And since Sun and Earth are the fundamentals of

our environment, Biology has been incorporating much of what it can learn of these, since Hippocrates, and earlier. Again, the humanistic studies inquire throughout the human past and its evolutionary heritages, seeking to continue these, and critically to distinguish good from evil. Ethical, psychological, and esthetic studies and applications similarly justify their part in this division of labour so far, yet only effectively as they keep touch with life, in which they arose, and ever need to return. In this wide sense, as we verify and realise the concept of Life in Evolution, all systems of philosophy have alike to be reconsidered, as studies directed, instinctively when not consciously, towards its general review and interpretation; in fact, as so many contributions towards what we must thus call—Biosophy.

To justify this whole argument, we now see the need—and why not possibility—of a Life-Theory; and this evolutionary throughout, from organisms at simplest to humanity at highest. In this due place must be found for each and all the contributory sciences, for the occupations and the arts, and for literatures and philosophies as well. Without, of course, pretending to discuss all this with any completeness—a task for the indefinite future—we have by this time the conditions for outlining the Life-process, both organic and social; and these broadly enough to indicate space for all we know of its varied Life-developments.

B. LIFE THEORY IN OUTLINE AND NOTATION

Beyond the all-too-often isolated, and thus static, conceptions of Environment and Organism, we have here to consider their actual and active linkage in life—indeed as Life. And this in its twofold aspect: since the Environment is so far determinist of the organism, yet the Organism reacts upon its environment, so far dominating it, or at least modifying it in turn. We have thus on each side of this life process a triple unity, a chord of life: so let us sum these into briefest possible notation, Environment functioning on organism as Efo, and Organism functioning on environment as Ofe. (Indeed, as we speak of nerves as afferent and efferent, might it not be clearer were we similarly here to speak of affunction and effunction?) To abate use of technical terms, and simplify to the utmost, let us begin, as so often throughout the history of biology, with what we know of our own human life, and at its simplest; for which none will deny that the general conception, of the Environment functioning on the organism, is far more simply and concretely realised in human observation and experience; as how each given Place (say on land or by sea) essentially determines the main work of its folk (Pwf); yet also how these Folk actively work to make the most of their place (Fwp). For in the first of these two life-chords, the natural conditions,

"natural advantages" or "resources," are first in view, and in the second the activity exercised upon them. Every organism, every human community, has obviously this two-fold aspect of its life-work; and hence our diagram must be made with two sides, in fact much like an account-book, as of receipts from Nature, and expenditure on it towards further result.

Yet a graphic method works far better than does book-keeping; and as the experience of crafts and games is that mind works best along with hand, let the reader give that principle a fair trial, needing but a little practice, of reconstructing our diagrams for himself; and so begin by folding a double sheet of note-paper, vertically, into three columns, on each side. On the left of these two opened pages, let us write at top of first column Pl for Environment or Place, and at bottom of its third column Fk, for organism or Folk, so leave the middle for function or work (and, to avoid two F's, say Wk for main life-work, as determined by environment). So this outline reads as:

(E or) Pl		
	Wk	
		(O or) Fk

GEOGRAPHY, ECONOMICS, AND ANTHROPOLOGY.—Next recall, as noted above, that in our city, its Geographic, Economic, and Anthropological studies and discussions are carried on apart, in so many Societies, and in our University in so many Departments, and thus all as separate specialisms. So to express this, we must fold up our diagram vertically, into a three-sided prism, on which we can thus no longer see all three at once; but only one at a time. Next, let us ask, what is it that these effect; what do they respectively produce for us? The Geographers are ready with their answer: they show us their maps and atlases, their globe: each an admirable condensation of knowledge, embodying ages of exploration and discovery, with modern accuracy of topographic survey to boot. Yet we must be pardoned for saying that the human interest is still far from complete; our town is more than a black dot, or even a plan. We pass to the Anthropologist, who duly impresses us by his vast collection of skulls, flints, and other human remains of interest. But when he and we have no longer our Place, with our activities in it (Work), we shall be dead; and little of us will endure, save perhaps our skulls for future collections and measurements, and say our spectacles too, which may earn some such approving remark when shelved in the museum of the future, that "these twentieth century barbarians really polished their flints pretty well". And as for the

pure Economist, long and still so commonly apart from our everyday Place and Folk, how can his promised and professed study of Work be a real and working one? Is it not thus that he so coldly imagines his essential Place as "the Market," and abstractionalises Work into "Production and Exchange", and these regulated by an abstract Money-notation, in oscillations we cannot follow, nor sometimes he either; and all ruled by rival deities of "Supply and Demand". And that he also takes so little note of Folk, even abstracting the concrete and materially indispensable work-Folk, into Labour and Capital? Hence surely it is that to the lay mind his science has so long appeared the dismal one. Yet as human ecology, of "Man and his Work"—is it not the most generally interesting of all?

So let us leave now for a little these three sciences, thus at their coldest, since so far breaking up our conception of Life. We shall soon see that its notation will help us to study them at their best, when re-incorporated into the human life from which they each and all arose, and to which each, at its living best, returns. For with this fully biological outlook, geography and ecology, anthropology and evolution, are all at one in the understanding of Place, Work and People, in living interaction, psychological as well. And yet these are physical, biological, and social too. Life is the unity; its full study is synthetic; its analyses are but temporary divisions of labour, of which the results have ever to be incorporated into our understanding of Life, and thus into its graphically summarised chartings.

LIFE-DIAGRAM IN DEVELOPMENT.—Return, then, to our life diagram. Let us now for further clearness dot in two horizontal lines above and below Work. This now ninefold diagram will be easily retained as that of our childhood's "noughts and crosses", though the game on it is different. Three squares are occupied; but six are empty. How are we to fill them? The diagram thus begins to ask us questions, which demand thought, and soon elicit reply. It is thus like an abacus, or other helpful "thinking-machine". Begin, say, with Place and Folk: what ideas do their combinations afford when we qualify each by the other? Plainly fk-Pl and pl-Fk; i.e. folk-Place, and place-Folk, respectively. In familiar language we say Home and home-Folks: so our uninviting-looking notation already expresses the two earliest and most familiar ideas of our lives; and with their numberless connotations, even of simplest song—"Way down upon the old plantation, there are the old folks at home"; and many others each may recall. Enough to illustrate, and from the very first, how notations and rhythms, mathematics and music, intellect and emotion, are nearer than they seem, when unified in Life.

Next let us mutually relate Place and Work; obviously as place-

Work, i.e. the "natural advantages" of Place, needed to make Work possible; and also as work-Place, i.e. the place—field or workshop, etc., where the work has to be done.

Again associate Folk and Work: work-Folk is plain, and folk-Work obviously expresses their particular occupation. So now our diagram is filled up; and in all their essential ways in which environment as Place determines Work, and these the organism or Folk. In summary then:

PLACE	pl-Work	pl-Folk
wk-Place	WORK	wk-Folk
fk-Place	fk-Work	FOLK

RE-CO-ORDINATION OF GEOGRAPHY, ECONOMICS, AND ANTHROPOLOGY.—Now with this graphic outline rationally developed before us, let us make out what has happened to our Geography, Economics, and Anthropology?—since at first seeming respectively limited, to Place, Work, or Folk alone; and these each only touching at a point; which may express their too limited contacts while kept specialisms at strictest. But we now see how at their best their claims and endeavours have always been larger. For the true Geographer has ever been really interested in all aspects and influences of Place, and the true Anthropologist in the like for Folk; and so too the true Economist also (there have been and there are such) as fully for real Work, in all its aspects and relations. But here in this diagram is, so far as we know, the first attempt towards realising with simplicity, yet clearness, the exact interrelations of these three studies, and of what they represent in the web of social life. To bring this out with precision, suppose we draw vertically a green line, down the column of Place, a red line down that of Folk; and, not to be too optimistic about Work, say a black one with pen or lead pencil down its column. Yet immediately we see that each of these three subjects needs its horizontal colour line as well: for each of their most living students, and specially when travellers, or even tourists, has noticed how his subject affects and is qualified by the others also. More concretely stated, the geographic traveller through Place notices not only work-Places and folk-Places but is alert for place-Work (natural advantages) and also for place-Folk (natives or denizens). So, too, the anthropologist, again especially as traveller, goes not only vertically upward, in our column for work-Folk and place-

Folk, but along to the left as well, so entering the field of economics, specially as regards folk-Work (Occupations), and studying the folk-Places (Homes) as well. The economist too can hardly but start with place-Work (natural advantages); and consider folk-Work (occupation) with due care: and his interest is also turned to left and right of his central square, to work-Place and work-Folk respectively. But if so, our diagram now stands out clear in its three-fold interweaving of all three studies into unity: and with its distinctive colours yielding a mingled yet definite pattern, it becomes plain that we have here the varied web of social life. The weaving goes on everywhere; its webs are woven for themselves by the children of men in all lands and times, from poorest and simplest to richest and most developed. If so—and if a familiar northern simile be permitted us—have we not here the very Tartan of Clan-Adam?

But for a more scientific name, what shall we call this? It must be confessed, however, that a convenient scientific name for this geographic-economic-anthropologic web has been long of coming; and that triple name is somewhat ponderous, though short and simple as compared with the nomenclature of chemistry. The needed name is but a century old—Sociology. No doubt this is at its very simplest; all the above is but elementary, indeed elemental: but open to further development, indeed, needing it, since so far from complete. Yet here is the actual beginning of our Edinburgh School of Sociology many years ago, incorporating all it could from current science; so at once Le Play's *Lieu, Travail, Famille,* and Comte's and Spencer's classification and inter-relation of "Physical, Biological, and Social Sciences"—and these more the same than either of these eminent pioneers ever realised, or their disciples either. We utilised the geography of the schools of Le Play, Tourville and Demolins, and Reclus, the anthropology of Tylor, Haddon, and others, and such further aid as we could muster also. In the same way the Sociological Society was next recruited; again especially among the geographers, economists, and anthropologists, most open to mutual interests; and thereafter lodged in "Le Play House" accordingly; since on the whole his example, contributions, and influence towards this co-ordinated treatment have been the most concrete of any so far, and are now extending through surveys, even to economic and social teaching, as it advances.

But it may be said this diagram, even if so far co-ordinated, is but a faint outline. True: it gives but briefest possible indications, yet towards arranging and selecting, from three bibliographies, each indefinitely voluminous: and so yielding fuller social descriptions and tabular summaries, on a better method than that of Herbert Spencer's elaborate folios. The long files of *La Reforme Sociale* et *La Science Sociale,* the earlier and later magazines of the respective schools arising round Le Play, furnish an example of

attempts to co-ordinate this literature; while the mass of it is, of course, in the innumerable records of geographical and anthropological travellers, of descriptive economists also, like Arthur Young, Cobbett, and many more; not to speak of many other sources, even from novel, drama, and poetry to the sacred books of the world. The above outline has, however, primarily arisen, as a matter of theory, from the attempt to clarify and co-ordinate the sociology of the Le Play school with the progress arising from or since Comte. Yet also as a matter of practice, from actual Surveys of many cities, and sometimes of their regions, and the attempt towards putting Reports for their town-planning and improvement on a more orderly and comprehensive corresponding basis. Yet as town-planning has fundamentally arisen from the need of hygiene and education, and from the work of building and gardening, and all these as fundamental occupations of biotechnic and bio-social character, this whole way of study and presentment goes back to Biology: and this as generalising our nature-studies. And as town-planning is but the endeavour towards amending and renewing the human hive, its experience affords a very suggestive line of biological and evolutionary inquiry, as well as of application. Indeed, thus to amplify our outline Life-diagram far beyond present limits would be easy: suffice it here to point out a single illustrative detail. The geographic Atlas can at utmost give but a few town-plans, and Baedeker and other guide-books a few more. But the town-planner specialises on these, into details previously unmapped, even by Ordnance Survey; since sometimes knowing his city to the very quality of house by house, and their main types of occupants too: while henceforth to dot in the line between work-Place and folk-Place on our diagram, i.e. to separate factories and homes, so messed up together by the industrial age, and to the grievous deterioration of them both—is technically known as the "Zoning", of recent years in progress. What is this but human hive-building?

PLACE		
work-Pl	WORK	
folk-Pl		FOLK

Further Possible Developments of Life-Schema.—What now for more general use, yet towards fuller specialism also, and over these whole nine fields? Note in square of Folk, the two sexes,

and younger and elder ages, from babehood to patriarchate: so our square of Folk must keep note of all this, and with four main divisions, for youngers and elders of each sex. Whence room for fuller study of sex and family, each a vast subject in itself, and each duly touched on in this book. Next Work; so start with "the economic man" at simplest, of whom the type is Robinson Crusoe, and he with hard work accordingly. But when Friday becomes of aid, there arises a division of labour, in which Robinson henceforth takes directive part. Their labours yield a well-earned store of corn, partly their daily wages, their food-store for their time of prosperous leisure also, and partly saved as agricultural capital, potential towards next sowing. So here are the three essentials of classical economics; labouring, directing, and capitalistic; seeming sufficient until Marx disclosed the significance of labour left potential as unemployed; and so with consequences needing no exposition here, beyond that of completing the logical fourfold subdivision of the Work-square. Finally Place ranges from one's own seat or bed or standing room, to the wide world; and in all these we are at rest or in motion by turns. Note finally that though these fourfold analyses of Place, Work, and Folk are the universally known and accepted ones, they have but to be put into their squares to bring out their congruence. Thus it is man who does the executive and directive labour of most occupations, and woman more of the general economy of family life; while in place she is domiciled, while her men-folks fare afar. So the compounding of Place, Work, and Folk is a far complexer task than at first sight appeared, since now resulting in fourfold arrangement of each and every square—specialising them into 36, from the initial 9. The like sub-division will often be found helpful in biology too, and notably for social creatures—ants, bees, etc.—else it would not here have been mentioned.

THE NEED FOR A PSYCHOLOGY.—Enough, however, of this first outline of social life, and correspondingly towards its science, alive also. It is now time to consider its deficiencies: what are these? First of all, no psychology! Without something clear of that, we are but beginners; what is to be done? The old economic psychology has had its long day, but is now discarded by every existing school of psychologists, and even derided as futilitarian. Strict geographers can say nothing of it; and travellers, even as anthropologists, have not yet systematised their wealth of observations and shrewd interpretations. So we must go to the professed psychologists, and to begin with, our experimental colleague in his laboratory. He asks who we are, and we reply that we were formerly occupied as geographer, economist, and anthropologist respectively, but now we have come to agreement and co-operation as three musketeers in the common cause of social science; we see this is too elementary

since we have no adequate psychology; and we come to you to teach us. We plead, as students, so he consents. He shows us far more than we knew of our senses; he finds out how far our experience of fatigue is genuine or really only laziness; or again how far we may be over-fatigued and yet not realise it; and he even tells us some-something about our feelings. But when we ask—how does all this bear on social science?—he has little or no answer. But as we go, the geographer exclaims: "Sense!—That place I am surveying impresses my senses, and I turn them on it and observe it." Then the economist: "Since I got behind the market, and interested in real work, I am getting some experience in my workshop and garden, and doing ever so much better than at first." And the anthropologist: "Since I got beyond measuring skulls to these real people I've been with in Polynesia, I've had quite a feeling for them. And I got on with them too."

So this is the sort of elementary psychology we were looking for. Place-Sense, Work-Experience, Folk-Feeling: there is our scheme, now far more alive than before. We soon see too that we shall have to compound these psychologic elements also with each other through the other six squares as well. So here it is.

PLACE ——— SENSE	place-Work ——— sense-Experience	place-Folk ——— sensed-Feeling
work-Place ——— experienced-Sense	WORK ——— EXPERIENCE	work-Folk ——— experienced-Feeling
folk-Place ——— feeling-Sense	folk-Work ——— feeling-Experience	FOLK ——— FEELING

Psychology at Simplest.—What use is this diagram? Can this outline-psychology really help us? First of all by its very simplicity; for here we have got down to fundamentals, since all this psychology we have in common with our own dog and even cat. They both know the place, and as home, and the home folks too; they have experience, and use sense-experience and show feeling-experience, at their work of rabbit-chasing, mousing, and so on; every one of these nine elements is more or less plainly verifiable in their ways of life. So is not this the essential outline and starting-point for comparative and human psychology alike, since applicable for tracing downwards to simpler animals, and upwards to man, from childhood onwards? So to aid familiarity with this outline and bring out its

uses, note how as we have a feeling-Sense for our folk-Place, and a sensed-Feeling for our place-Folk, we have experienced-Sense in our work-Place: thus sailor and landsman are each experienced and observant in his own work and way, but that alone. Again recall how in first practical lessons, say at piano, we were first called to sense-Experience, to observe not to strike the wrong keys: by and by we had Experience enough to get through our piece, though too mechanically; while the teacher strove by example to deepen this to feeling-Experience: so here is the traditional and normal development, of prentice, journeyman, and master. Again, where shall we look for more experienced-Feeling than among work-Folk at their normal best; since they have through life fully laboured and suffered, more than we, yet not without life's joys as well. Our strict and formal diagram is thus not only synthetic and comparative; it is organic and human throughout. Yet notice that our psychology so far seems essentially determined by the bio-social conditions of its first outline, without psychology. It is something to have any psychology at all, and still more this in intimate relation with this elemental organic and social life: for we are thus freed from an apsychic biology, geography, economics, and anthropology, from the outset. Be it noted that this simple psychology seems, at first at least, what Huxley called "epiphenomenal"; yet it differs from this, and from mere parallelism in the measure in which each of these psychologic elements is reacting more or less upon its associated biologic or social factor. Yet after all, this simple psychology seems to have but secondary status, in which bodily conditions and functionings have the major part; for what answer has it to the "Lange-James" theory; that we are sorry because we weep, and merry because we laugh? If so, our psychology is essentially subordinate: it is Bio-psychosis, mere Body-mind; where shall we look for Psycho-biosis, Mind-body? Are we to be shut up, or driven back to the simple psychology of Loeb, with its tropisms? In a word, is our psychology simply physiological after all?

So far then this beginning; as yet only for Pwf and Efo. How shall we express the other and more active side, of Fwp and Ofe? At first by simple mirror-reversal, from left hand to right; and now upwards our two folded halves are thus symmetric, to their vertical co-ordinate.

Notice, however, as we set about reading this simple diagram, previously explained, that the order for this is reversed; for Fwp and Ofe, the more fully living and active side of our dual life-process, now reads from Folk and Organism, and thus upwards, and to the right. Active Folk react more fully on modifying their place, and active Organism more actively on its environment. And both are distinctly moved by Feeling. Their work or functioning is improved by memory-retained and nerve-cell-registered experience, con-

ditioning habit or instinct; so the sensed place, the environment, is now actively modified. Here, then our psychological life-factor is acquiring new and initiative importance: this side of life is no longer mere Bio-psychosis, but Psycho-biosis, as animal and child, let alone human adult, so readily show. Each is now something of Mind-body, not merely of Body-mind. In our first half-schema of relative passivity, in acceptance of environmental conditions and stimuli, life is seen as in the main determined by its circumstances: but now here, on this side, it begins to determine them: in short, here comes into evidence the urge of life—*libido, élan vital*—and as psycho-organic. Every success in the modification of environment has in it something of adaptation, and this two-fold. For underlying this bodily action we find a psychic factor. Resultant to activity, we find some adaptation of organism also, and surely so far psychic, together with such measure of external achievement as may be; i.e. of relevant environmental change.

Here, now, in the animal world, we have already a basis for widening survey. Recall how in many groups we find striking contrasts of passivity and activity, as from less or more sedentary forms, to swimming and active ones; as in coelenterates, worms, molluscs, crustaceans, and even insects; and much of the same in higher forms. Thus even the largely sessile Ascidians have active congeners; and in every group of Vertebrates something of the like can be seen, as to extreme in the contrast of the nimble lizard or snake and the passive tortoise, yet with something of the like contrast within their families as well. On the whole, the passive types tend to live by accepting what nature gives; while the active take more from nature. On the active side is corresponding progress: on the other more of passive adaptation; and even to degeneration in many cases. Plants extremely depend on environment, needing little beyond soil, water, atmosphere, and light; so though active psycho-biosis is not easily demonstrated, we cannot but wonder at their amazing sensibility, as demonstrated from Darwin's experiments to Bose's.

We must not forget that each of these two aspects of life is in speedy succession and alternation; the life process does not stand still, but oscillates; and that continually; so that practice makes perfect; yet how? Surely in the measure of psychic co-ordination, however sub-conscious. Now to all this it is no adequate answer to say, with Loeb and others, that the specific movements of animals under given stimulus are enough for understanding them; since our own simplest pain or pleasure—say according to whether we sit down on a drawing pin or a cushion, or taste bitter fruit or sweet —is enough for us to realise that life has its psychological side too; and this for simpler beings than ourselves; and even that this line

of explanation may be—in fact is—needed to explain many if not all movements evoked by different stimuli, however alike material. In short, then, the apsychic biology was nothing better or stronger than are other conventions and survivals in culture; although we remain physiological enough not to venture into psychology or philosophy disembodied from organic life, until we come into discourse with such philosophers, and find them worthy of them.

If so, "Biology" and "Psychology" are but convenient terms for associated and reciprocal life-aspects; and thus each but a partial presentment of Life's science, as is the distinctness of concave and convex sides for the study of a circle or other curve. The real phenomena for us are these of Body-mind and Mind-body—Bio-psychosis and Psycho-biosis. Though in ordinary language we go on with the familiar terms of Biology and Psychology, there is no escaping the fact that neither can ignore the interacting existence of both these processes in the phenomena they describe. The biologist but approaches from the former side; and the psychologist is more interested in the latter.

Hence our two half-diagrams may now be conveniently abbreviated and unified; yet also amplified, by introduction of concave and convex curves on left and right; so here by parenthesis-marks, set sideways, between organic and psychic terms in each case, and thus in opposite positions on the two sides. Their converse mode of interaction may now be read accordingly. On the left side, of Pwf or Efo, Environment impresses sense in its receptive cup; and so on throughout. But on the other side, Feeling presses Organism (or Folk) upwards, to urge of functioning; and thus on environment, discerned also from within. Hence on this side the capitals and smalls are reversed, to express what we take to be their respective importance; now on the right in Psycho-biosis, Mind-body, and not, as on the left, in Bio-psychosis, Body-mind.

$$\begin{array}{ccccccc}
\downarrow & \underset{\mathrm{Se}}{\overset{\mathrm{PL}}{\smile}} & & \longrightarrow & & \underset{\mathrm{SE}}{\overset{\mathrm{Pl}}{\frown}} & \uparrow \\
& & \underset{\mathrm{exp}}{\overset{\mathrm{WK}}{\smile}} & \longrightarrow & \underset{\mathrm{EXP}}{\overset{\mathrm{Wk}}{\frown}} & & \\
& & & \underset{\mathrm{fg}}{\overset{\mathrm{FK}}{\smile}} \longrightarrow \underset{\mathrm{FG}}{\overset{\mathrm{Fk}}{\frown}} & & &
\end{array}$$

$$\left\{\begin{array}{l}\text{Bio-psychosis}\\ \text{Body-mind}\end{array}\right\} \longrightarrow \left\{\begin{array}{l}\text{Psycho-biosis}\\ \text{Mind-body}\end{array}\right\}$$

CRITICISMS TOWARDS IMPROVEMENT.—Yet on which side shall we set this or that example of life's functioning? Has it not, often at least, something of both? Does even a root merely passively absorb

water, like the earth it inhabits? Is not the poet true-sighted, when he notes how root and shoot in their activity "clutch the earth, and seek the blue!" If so, our passive view, our naively apsychic physiology, here becomes active, and even something of psycho-physiological; and the like for thirst and hunger, for light-seeking and for mate-seeking, throughout living nature. Still, this view does not in the least affect the legitimate and necessarily strict experimental thoroughness of physical and physiological inquiry, since life has ever to make the physiological best it can of such external conditions as it has, and of its internal conditions too as best it may; for on all these adjustments and adaptations depend its survival and its continuance. So physiology and psychology have each so far their field; yet all the better for synthesis, when we also correlate them, as fully as may be, into the unity of Life.

Yet note still further, that instead of reducing our first half-diagram, Efo or Pwf, to its barest, we have rather to keep on incorporating into it all we can from the other and active side. For our human environment, our place, embodies the past achievement-heritage of our predecessors, the material and even psychic heritage of every field, still more of garden and home; and all we reclaim or plant or build will soon belong to our successors; as the like for coral reef, for bee-hive or ant-hill, for rookery or beaver-dam. Similarly something of the co-ordination of active functioning on the right side is retained towards more efficiency upon the left; and surely also its feeling deepened also. In fact is not this going on in every individual development, and in community life as well?

Hence if the above diagram be scrutinised, its order of beginning —with Pwf or Efo, the passive side first, and thence passing to the active side, of Fwp and Ofe—is seen to be too much a matter of convenience for explanation, as with Locke's famous assumption of the mind as like a sheet of white paper, on which outward sense-impressions make their imprint. This arrangement also conveniently follows the process and development of the reflex action, from stimulus to response, like winking when something comes too near the eye. But the organism is in active life from earliest development; so much may be said for putting these halves in opposite positions, the active first. Yet in fact the real diagram needs to be one of indefinite succession, whichever we begin with—so throughout life.

Pwf—Fwp—Pwf—Fwp—Pwf—Fwp—Pwf—etc., with which we must also keep in mind the interacting psychologic elements, and in their also alternating order. Yet above we have still begun, and ended, with Pwf; so as to express the first awaking impulse to nascent life from the environmental side, and then the final predominance of environment at life's close.

The Efo and Pwf side of the diagram includes active functioning

and work: but this would naturally first appear on the active side; especially so in human life, in which work proper begins so late. For present purpose, however, any externally applied organic activity may be considered work, as by the physicist. Even the senses of the active organism are aroused and trained by attention to the environment, for food, etc., more than by passive acceptance of impressions; and so for its experience from active work, and its feelings, in higher forms especially, from active contact with its kind; yet also in hunger, in the avoidance of danger, etc. So all this active side of life is training and developing the passive side, in its growth more efficient in turn. All this we can now express by developing our diagram further, say with italic lettering for the active process. Thus:

Fwp—P′w′f′—*F′w′p′*—P″w″f″—etc.

Here, too, we have added accents, to express the cumulative organic development throughout the life-process; with which we must bear in mind also the psychic accompaniment, as on the active side the more important of the two, yet being advanced upon the passive also. The gradual development of our diagram is thus expressing that of our psychology. Hence, instead of reducing our first half-diagram, Efo or Pwf, to its barest, we have in practice, as above pointed out, to develop and enrich each and all its six elements from the other and active side, as this advances in the above succession.

So strong has been the tradition of the older analytical psychology, be this of "faculties" or "association", or in later forms, that the regular squares of these diagrams may be misunderstood, as but analytic also. Yet these lines are not walls of separation, but more like the parallels and meridians of the globe, which in no way mar its continuity, but make our sphere more intelligible, and comprehensible from our various points of view, and lives of course. Thus we do not think of sense or sensation apart, but as a necessary and inseparable element of its chord of life, giving and taking from the others; and so again for the other chords and elements of the fourfold interaction of Acts and Facts with Thoughts and Deeds, here suggested. All this life-process, despite its many aspects, has the simplicity (yet complexity) of unity in Life—and thus much like a dual pendulum-swing or an inspiration and expiration: yet making up the full succession of heart-beats and life-beats, within and throughout the long and changing succession of the rhythmic, yet ever varied, development, maturity, and decline of life, with its changes, alike in internal adjustments and outward adaptations.

LOGIC AND TECHNIQUE OF LIFE-GRAPHS.—If we seek, as in science we must, to clarify our conceptions to the utmost, and thus

crystallise our still too vague treatment of "natural history" into a rational ecology, we need logic, and logic at its best and clearest.

The ordinary logic of induction from observation and experience, and of deduction from clearly ascertained principles is all very well so far as it goes: but—to confess the very worst—we need also the main logical advance made by Hegel, and this further clarified, by use of the co-ordinates of Descartes! Yet these, for practical purposes, so far from leading us into the deep and intricate speculations of the philosopher, or the high and refined elaborations of the mathematician, turn out to be as simple as is the multiplication table in its earliest beginnings; since we only need that of one and one, two and four, for all of Hegel we require, and the like extended to three, for the theory of life.

Recall, then, the simple key with which Hegel opens his labyrinths, which we do not need to enter: namely, that while the Greeks long debated between thesis and antithesis—e.g. virtue and vice, love and hatred, truth and error, beauty and ugliness—we can clarify Aristotle's solution, of finding "the golden mean" between these extremes, into Hegel's more definite "synthesis". Thus let W represent white, and B black, its antithesis: their synthesis will obviously be their Aristotelian mean, which we call grey. But, says Hegel—in principle, though we use this simple illustration of it—this synthesis does not really absorb and unify our thesis and antithesis of white and black into harmony as synthesis finished and done with. For the original antithesis is still also present; since we see (at once visually and logically) that grey can and does range to light grey and to dark grey; hence preserving more or less of the old contrast, as well as of the new harmony. In another connection, Hegel images for us the owl of philosophy emerging at dusk; so we may here use this to recall how its grey plumage seems dark against the twilight, yet light against its shadows, of coming dark. Next put this main idea into graphic form—which Hegel, like philosophers generally, fails to provide; so too often leaving those who might be their clearest readers in twilight of understanding. Given W and B for White and Black, their antithesis can then be graphed as $\begin{array}{c|c} W & \\ \hline & B \end{array}$. Their ideal synthesis, as medium grey, is thus but their meeting-point, at intersection of their separating lines; but these leave two spaces for two less perfect syntheses, in $\begin{array}{c|c} W & wB \\ \hline bW & B \end{array}$, in which white is but darkened, and black but lightened; in short, light grey on left and dark-grey on right. Each is so far in its way a pro-synthesis; yet to the other it is also a counter-synthesis; since much of the initial antithesis between white and black still appears. And these, when we graduatedly shade their spaces, will always show something of the same antithesis within the light grey, and the dark-grey spaces themselves. Here, then, is a form of graph, which like so many others, can be put to the most varied uses, say for historically recalling the shades of opinion in any great field

of discussion; or biologically applied, as to the plotting out of variations, whether arising from mingled heredity, or from other causes.

Further use indeed is to make Hegel himself more clear to his readers (if not even than he was to himself). Take what seems the most triumphant case of his synthetic reconciliation of the antithetic couple which before him seemed absolute and irreconcilable, viz. that of Being and Not-Being. For does not common sense seem uncompromisingly to insist on one or other—for how can anything be, and yet not be, at once? Yet the solution comes, as simply as with Columbus' egg—for Hegel's answer is—Becoming! Yet this Becoming may be towards Being, as with the child and youth, not yet man; or with the old Man at his maturest, yet all the further on his way to Not-Being. To the historian, well as the biographer, to the embryologist and evolutionist, these different directions of Becoming are obviously essential. So, instead of so many words, why not write:

$$\uparrow \ \frac{\text{BEING}}{\text{Becoming}} \,\Bigg|\, \frac{\text{Becoming}}{\text{NOT-BEING}} \ \downarrow$$

This method will be found suggestive in stating and thinking over other biological problems. Thus, male and female (M and F):

$$\frac{F}{\quad} \,\Big|\, \frac{\quad}{M} \quad \text{suggests} \quad \frac{F}{mF} \,\Big|\, \frac{fM}{M}$$

i.e. masculoid females (say crowing hens), as mF, and feminoid males (say capons) as fM. We might adapt this method to the origin of species, at least in certain cases to begin with, as for feminoid and masculoid species, e.g. bee and wasp, sheep and goat.

FACTORS OF PSYCHIC AROUSAL, NUTRITIVE AND REPRODUCTIVE.—It is a main value of any diagram that its bareness suggests further inquiry. Recall, then, that feeling, alike in animal and man, is not simply aroused from the ordinary life-maintaining inorganic conditions of its environment, but by its clamant organic needs; and these, fundamentally and most of the time, are of self-maintaining character, of nutrition, for growth or adult maintenance. Yet are not these surpassed, and more and more, as we ascend the organic scale from simplest to highest, by the ever intenser and more stressing urge of species-continuance; in a word, of reproduction, and thus increasingly, up to and with the evolution of sex. With the full development of this urge, the individual attains organic maturity and commonly ends its growth: correspondingly such psychical development as it may attain matures also: and both unite in recurrent reproductive urge, raising life on its psychic side to high and higher intensity of feeling, despite the consequences, of temporary or even final exhaustion of the body. In such psychic develop-

ment, in which the simple feelings of life-maintenance are overpowered, we have manifestly the spring of what we may henceforth rightly distinguish as Emotions, and which even before Darwin's fundamental "Expression of the Emotions" have been plainly traceable from innumerable simple animals upwards, to peacock and skylark, and from plain man to poet.

More and more then, we see how our left-hand half-diagram, Pwf, has ever been gaining and incorporating more and more from the right. Baby does not really sense, move or feel definitely at first, beyond "buzzing and booming confusion", as William James puts it: and his later sense-experience and feeling is, very largely at least, an acquirement from his more active life. In the more passive animal types, it is therefore no wonder that we so often find regression rather than progress, and this carried to extreme in the parasite, not despite but because of its optimum conditions of nutrition aud safe protection from the active experiences of life. Evolution proper is far more compatible with the active life; and through mastering its difficulties, facing its dangers.

How these advance the individual life, and stir it to that effort, and even selective choice, to which we cannot refuse some beginning of intelligence, and of which steps are traceable from a case-building protozoon to an architect, has long been manifest. And similarly for the emotional arousal by the reproductive urge. We cannot here enter into the still far from settled questions of the rise of man's psychologic nature, from simplest to highest recorded levels, though in the next diagram we shall attempt this in outline. Yet that human thought, up to its utmost creativeness, is deeply evolved from these simple urges of self and sex, we have increasing evidence since our own *Evolution of Sex* (1889); as so notably of late years from Freud's and kindred studies of sex, starting from the pathological and abnormal side, so with contemporary interest centred around the theories and methods of psycho-analysis. But long before these, one recalls from Paris student-life—than which we know of none more strenuously intellectual—the not infrequent saying: "Il faut faire passer son sexe par son cerveau!" For here is surely a main secret of the origin of effective and creative thought of all kinds. For this master-urge is thus sublimated, and turned to intensifying and widening the self-thought as well, and thus with unified outcome. Each in its way is significant, yet advancing (or retarding) community culture and personal individuality together; as is manifest from the ruthless outspokenness of Zola's *Germinal* to the all-transcendant Paradise of Dante. As intermediate type, let us take Schiller, to whom none will deny idealism: yet he reminds us that "while philosophers are disputing about the government of the world, hunger and love are performing the task". And Goethe—a true naturalist and evolutionist—says the like in a well-known verse.

Indeed, what clear-thinking poet would deny these life-urges as thought-arousing for his own development, but rather confess it more frankly than do ordinary men?

THINGS AND THOUGHTS.—Hence, though we cannot explain consciousness and its outcomes in terms of brain anatomy and histology, we know enough of their correlation to be convinced of their productive interaction: since from simplest to highest evolution we see material and outward things affecting and arousing sense, instinct, intelligence, and feeling; and conversely the emotioned urge of life physiologically effecting changes of things, both within and without. Biology and Psychology are thus ever interacting throughout life, and as Bio-psychosis and Psycho-biosis—Body-mind and Mind-body; and their associated study is profitable, even necessary, beyond the—surely passing—specialisations upon either, in artificial isolation from the other. Physiologists, with their legitimate specialisms, have usually kept the bodily life together; and psychologists have made attractive presentments of their aspect of life with but little reference to the other: yet let us be impartial, and take both, reconciling and co-ordinating them as far as we may. Too crude attempts at this reconciliation have already been made; witness the utilitarian philosophers, and the hedonistic psychology of past economists. Yet their extremes of hedonism, serviceable though these may have been in recalling pure psychologists to physiology, and vice versa, fall short of the evolutionary interaction of things and thoughts, thoughts and things, in these pages so repeatedly pled for, though still to be further outlined. Yet before setting about this, a vivid personal experience may at once illustrate the argument, and relieve its form of presentment.

AN ACTUAL DREAM.—After long and perplexed thinking—of how it has come to be that Life, and its evolutionary developments and expression, still so generally fail to interest either the experts of the physical world or the scholars of the humanities—came sleep, and then dream. In the vast hall of a great building its organ is taking shape. Its main pipes, stops, and swells are already in place: the musician is at his keyboard, and the audience encouragingly streams in. But they are gesticulating in active debate with each other; and as they come nearer, he finds with astonishment they are deaf, and so wonders what interests them here. For most, he finds the interest of the organ is as a great and complex machine; or, for a few others, an unusual form of architectural façade: but neither discern its real nature, much less its possibilities. A scholarly group open and scrutinise the music-books; but when he hopefully turns to them, he finds it is their strange notation and printing which interests them; and that they conceive of such characters, such books in libraries as all that music has to offer; for they too are deaf.

A new group enters by the eastern door; and he is relieved to find them free from these various material views of the West, indeed frankly contemptuous or pitying of them. They know that music is in the soul; but, alas, there they leave it: they have no use for his organ, his scores, or his active voicing of them; for them all alike are but material and external: so they are deaf to him also. And though many bear upon their breast or brow an outward and visible symbol of the movement of life, they have too often turned it the wrong way.

Wellnigh in despair, he makes sign for silence: he begins to play, but none listen; he can reach no ear! Indeed, each group shows dissatisfaction, and that increasingly; till at length, and from all sides, they pounce on him to tear him in pieces. So thus—as nightmare—ended this actual dream. Yet first it was a dream of hope, indeed of full confidence in the Muse-world of Life; and that in its unified material and psychic expression it could not but reach all minds—the esthetic, the mechanical, and the learned alike: or surely at least those of the Orient, with their inner life oftener awake, and more deeply cultivated. But neither the minds confined to external outlook, nor those of strictly interior meditation and discipline, suffice for this. Vital Synthesis is not reached by either: since Life, from its simplest to its highest manifestations, evolves through increasing interaction of the inward with the outward world, and conversely. With this conception hope returns, with faith in the possibilities of this full Muse-Organ of Life, even to the awaking and arousal of its spectators as auditors—sometimes even to organists in their turn.

To understand things in the world without, or thoughts in the world within, we must thus take them together. Yet no longer merely in the too abstract terms of "Subject" and "Object", but as Subject-object and Object-subject in perpetual interaction, as Psycho-biosis and Bio-psychosis, Mind-body and Body-mind; and these as expressed and observed in actual life, and interpreted from it. And all this as concretely and clearly as may be, throughout each and all Life's levels, lower to higher, past to present, and with due evolutionary forelook towards further possibilities. The intricacies and subtleties of epistemological controversies are thus practically and intelligibly harmonised; and, along with these, the too disembodied and too simply embodied psychologies, of idealistic and materialistic or behaviouristic schools.

THE DRAMATIC ASPECTS OF LIFE.—Place(s) Work Folk: Folk Work Place. What tiresome repetition! Yes, as words; but not as the characteristic sides and wards of the key of Life; with freshened realisation of how to apply it and of what one gains by that. For Place—as we come to realise it, and thus begin to understand it—is Cosmodrama: Work is Technodrama. Thus develops for each

Individual, as for his Folk, the Autodrama of simple life. When this widens, into co-emotion and Community, we have (Etho) Politodrama, of which the positive (or negative) Synergy is ever making History. This becomes intelligible, as Chronodrama; while the imaged achievement is so far Eudrama, when not the opposite. What, then is this whole Biodrama? At best the Syndrama, of Evolution.

Next, with our Place realised as in Cosmic drama, and Work in Technodrama, consider their interactions. For in work-Place we can not only, as usual, observantly apply our experience-Sense, our technic productivity, and Experience, to better Work, but enhance our experienced-Sense to veritable Discovery; and continue this in our work-place, now laboratory, to further discoveries still. Conversely, as sense-experience sharpens into knowing our natural resources, and towards better use of them, we have not only discoveries, but are thus also in the way of Inventions.

Thus when in laboratory we use the technic masterpiece called microscope, the dirty water-drop may reveal new marvels: while telescope or spectroscope open yet greater discoveries. Conversely, as our physical nature-knowledge grows and deepens, and we apply this, our technical powers increase to invention. Thus life trains for discovery and invention, and these in reciprocal advance—hence the significance of modern research, in each field or both.

If, then, these examples of the logic of life are clear, what hinders us from further developments, in each of these fields of life? And what also from continuing the same thought-game further, so as to see the interactions of each of these other sub-dramas, and even the results to the whole? Space prevents elaborating this: but all the better if the reader play this thought-game for himself—of course with some needed patience, as for the solitary game so-called.

It will be evident that in such development, of Efo or Pwf, these have incorporated much from the other side, of Ofe, Fwp: and that in our discovery and invention we are also developing all that, and bringing it to bear more and more. Yet, such achievement, such supposed "talent" or even "genius" to make them, is but of Life, and in Life in evolution. If so, what we call "ordinary life" is but its arrest; whence too much of what it calls "education"—be this "technical" or verbalist—inhibits rise beyond that level. Yet if man have really discovery and invention open to him, waiting for him, what he mainly needs is release, to enter on productive careers creatively intellectual, practical, or both. And the like in each and all the other interacting elements of the Life-drama. Again, then, it becomes clear that the Super-man is within man, and needs no external tyrant to repress him: yet more of social thought and applied wisdom, wise and wide enough to aid release, and to enrich opportunity.

ORIGIN OF HIGHER FACULTIES?—Is not this a crucial problem and puzzle before the evolutionist? It is now relatively easy to trace the evolution of man's form and face from ruder ancestors, since "missing links" have been and are being found from time to time: but as for the origin of his higher psychology, so far beyond the brute's and even the highest ape's—that has always seemed a far harder matter. So much so, indeed, that while Darwin and other evolutionists mostly have avoided this question, and some have simply begged it, we have had the striking case of Darwin's foremost contemporary, Alfred Russel Wallace, who having pondered much on the question of how either the mathematical, the musical, or the philosophical faculty, and the like, could have arisen, and been selected for survival in their early struggles for existence, candidly avowed his failure; and fell back upon the hypothesis of "a spiritual influx" for them; in other words a practical return to the very doctrine of special creation which he had done so much to replace by his own evolutionary one. But however this answer did credit to his candour in admitting his difficulty, and to his intellectual persistence in seeking some explanation, it is obviously incompatible with the general concept of evolution, and even that general faith in the order and unity of the universe, which science as well as theology firmly holds by, though each in its own way. Hence, as evolutionists, we cannot give up this problem; but we must give it another trial. First of all, since no naturalistic evolutionist—even the most indifferent we can imagine to religions with their doctrines, symbolisms, and mysticisms, to philosophy with its many and distinctive systems, to mathematics with its labyrinthine and abstruse developments, or to arts and music, poetry and drama—would for a moment deny their existence: he would still think of them as somehow products of human evolution, however outside his particular field, and so to him irrelevant, if not disturbing. Thus we have to take him with us, and face his criticism, even rouse his interest, in the quest of some rational and natural explanation of their respective origins; the more since he may admit on reflection that these may not be unrelated to the origin of his own scientific interests and powers—also not yet explained by him, evolutionist though he be. And as naturalist, he employs that sensing of his environment, that experience derived from activities, and that feeling for his kind, which man so plainly shares with the animal world, its higher forms especially. But his criticism is entitled to come in, and is indeed specially wanted, when we set out from these to explain those higher faculties of man which the animal has not attained to. Thus starting at the simplest and least controversial, let us each recall, from our visual sense, its memory-images—say of man, horse, and bird, all unmistakably distinct, and since earlier infancy than we can remember. Imagine next a good ride and

gallop together, which each of us, and each horse too, has enjoyed; since the man is thus virtually endowed with strength and speed far beyond his ordinary powers, and the animal roused to his fullest by encouraging mastery. What, then, more natural than that when man's mastery was new and wonderful, there should arise the splendid image of horse and man as one. Skilful fingers even shaped that vivid dream into actual form. Since then has not the Centaur galloped through man's imagination and mytho-poesy; and have we not freshened this for ourselves anew, by our own ride? And when at full gallop, and in that splendid leap, have we not had the nearest approach to flying possible to man before recent machines, and surely in some ways a finer one? How, then, can we help rejoicing when the artist models for us the winged Pegasus on frieze high overhead?

Kindred dreams, also derived and combined from familiar impressions, have also each had their day; yet even in ours they return to life for us when we wake from our conventionalised dullness, to vision them anew. Thus, what image more mysterious and significant, inviting yet appalling, than that union of woman's gentle and arresting face and tender bosom, with all their calm and dignity, yet set on the tigress's body? No wonder that this remains to us, from ancient Egypt, as still supreme symbol of her whose charm ever attracts, whose character ever perplexes us? We men cannot but realise how she reads us through and through, how she holds us in her power from cradle to grave, and this with gentleness of authority, yet at times with resistless stroke of talon as well. Again, the man-headed bull of Assyrian autocracy, the sinister Minotaur of Hellenic maiden-tribute to Cretan tyranny, are examples enough of how sense-impressions, emotionally recalled and combined, yield us imaginately creative art. There is here no external spiritual influx; it is but the arousal of the everyday mind to its deeper, higher, latent powers, and impelling, disciplining the hand to shape them. But if reader and writer, neither of us sculptors, try to make any such image, we shall find it no easy matter to shape man and horse as Centaur, or even give wings to Pegasus. If we give our lives to sculpture, we think out our design with all the anatomy we can master, and long labours as well; yet the freshness of the first imaging fails us, the work lacks life. Yet at some fresh emotioned moment our living imagery returns anew: we see the right changes to make, the touches to give life; so now the Centaur rides forth in all his glory. There then is the process of Art, from sense-impressions inwardly combined into vivid day dreams (it would seem rarely in dreams of sleep): thereafter designed and laboured. It may be long before it satisfies us, yet at length comes renewed emotion, raised to the level of poesy, which can be in marble or bronze, in colour or in music, as well as in speech and song. Thus is created an enduring work of art.

Next for the origin of Science, of course understood as no mere Roman empiric knowledge, or modern information, but the living Hellenic, neo-Hellenic, or even super-Hellenic logos. Its rise and development is again no insoluble mystery. Imagine ourselves now two neighbouring peasants, say on the Nile, whose inundation buries our separating boundary stone out of sight under its mud, or even undercuts it till it is lost in the stream. When ploughing-time comes, we each incline to think our space a furrow or two broader than it really is. Whence encroachment, and quarrel. Our wives, however, have more sense; they run to the Temple, and bring down its Measurer-priest, who comes with his record-book and his ropes (for geometry, in hieroglyphic character, is rope-stretching). He measures anew from a higher fixed point, and puts in a new stone, with his blessing on us while we respect it, his curse if we remove it: and so the matter is practically and peacefully settled. So much for land-surveying; a useful art, but not yet science. But by and by one of these bright Greeks comes along: he sees that one does not need a plough to make or conceive a straight line; nor earth to make a rectangle, nor yet a boundary stone if we wish to distinguish a point clearly. Thenceforward we have geometry as a science, developing in Greece, till Plato can put his matriculation condition over his Academic gate: "Let no man ignorant of Geometry enter here." The like of course for every science, as from nature study and herbal, to empiric anatomy and medicine, to Biology proper. The like from fire-kindling to Physics, from rolling tree-trunk to Mechanics, and so on; always the same step from empiric experience to vivid rationality. Mathematics readily rationalises to notations, applicable to concrete scientific problems, as from astronomy and mechanics onwards, towards the incipient and coming graphic presentment of all fields of science—the Bio-social last, and yet far from being excepted; as from our own simple attempts here, to the elaborations of "Biometrika".

But the mind is not satisfied with the sciences alone, even though marshalled from mathematical to social, and with their main inter-relations, as outlined in the "end-papers" in the binding of this book. It demands more, even to pro-synthesis of each and all kinds of knowledge. It seeks to appreciate their fullest significance, their "values" to the spirit. These are also emotional, as the very name of Philo-sophy expresses. Such Pro-synthesis as may be, humanly emotioned—so varying with the range and field, the life-experience, the temperament, as well as with the powers of the thinker—is not that Philosophy?

So here on the intellectual level, we have mathematics, science and philosophy, which make up the essential range of intellect at highest. Yet the philosopher, to whom the consent of each and every age has given the highest place, had his beginnings in life-

experience too, as the lives of Socrates, Plato and Aristotle each show, and later ones as well. Yet how human they were, have been, and are, and how educative their life-experience, are again manifest in all such lives, as even their abstract pages fail to conceal. Philosophy is thus the child of life-experience, although the parent of Wisdom. Hence the closer we look into the philosopher's life, the more his secret opens. Thus most have been essentially optimistic, or at least melioristic: Buddha of old, and Schopenhauer of recent times, are perhaps the only two pessimists we can call great. But little though they tell us of this, the facts remain, that the first lost his mother in infancy, and was brought up by a fond and foolish father: while Schopenhauer's is the yet rarer case—of lifelong and thorough incompatibility of temper of mother and son. No wonder then these were pessimists: life-experience, and its limitations too, cannot but underlie all that man can think; each being only evolves as it can. For a single and minor instance out of many possible ones, Adam Smith, in writing his *Wealth of Nations*, has (of course unconsciously, as even to his commentators) left us a very interesting outline-guide-book to his childhood and later home-town and neighbourhood of Kirkcaldy. Hence we have often concretely used it, in conducting survey excursions there: and with general interest, all thus understanding him, and his main ideas, more simply, more deeply, too, than in their university department of Economics, with lectures, library and all. To be convinced of this, the reader has only to make this excursion and read essential passages on the spot —of course reading in the concrete between the lines of abstract paragraphs.

Finally, if Art and Thought be thus intelligibly evolved, and essentially from Sense and Experience, what origin has Religion? Again, let us avoid conventional approaches. Imagine one of its memorable moments, say Moses' vision of the burning bush, that yet was not consumed. Not mere seeing a natural fire, which can consume whole forests, and with no divine vision to its spectators: but an inwardly emotioned and imaginative vision, that enhances natural beauty, sunlit at dawn or set, as when Blake saw his home tree "full of angels": and we are, of course, psychologists enough to know he did; though we should not all have seen them if we had been there. Given this vision of deepest emotional thrill, of mystic experience and ecstasy, he reflects on it long and often, brings all his intellect to bear upon it too. Emotion at deepest, intelligence at highest, clarify anew his inheritance of patriarchal monotheism (and Akhnaton's also) into that many-sided conception of Unity and Power, at highest, and of individual relation of Love as well as reverence; thenceforward fully established as central doctrine of the great religion for which he stands as main formulator, as thereafter to its later legislation in detail. How his life-experience, as we are

told it, fitted him for this leadership, has been the subject of sermons and commentaries beyond number: so enough here to note that in this high experience, and after a long fatherless childhood, youth, and early manhood, and now outcast from Egypt as well, his need of fatherhood at highest was realised, and his own mission, as soon thereafter father and leader of his people also. So much then for Emotion, mystic, yet social too, and also for its Doctrine, not only intellectualised emotion and vision, but with roots in long experienced folk-feeling as well. Of religion there is one other main and enduring element besides emotion and doctrine, that of symbol: hence the burning bush has ever since been glowing in Talmudist and kindred literature and teaching, flaming in medieval cathedral windows. It is the heraldic blazon and seal of each of the two Calvinistic Churches of Scotland which, after generations of rivalry, are reuniting on this very day when this page is being written. So may we not safely turn to our sceptical naturalistic colleague, and ask if we have not, with the above few examples, at least made reasonably clear the nature of our general claim—that the higher faculties, emotional, intellectual and imaginative, can be reasonably interpreted in terms of evolution, from the simpler ones of feeling, experience and sense, which we share with the higher animals. So is not this an outline explanation of how it is we have evolved to powers beyond theirs?

Yet have we not here also a viewpoint for better appreciation of animals, too, at their highest? Their mutual feeling, their "consciousness of kind", often rises to collective emotion and grouping, and this to more than to mere temporary crowd, but associated herd and flock, as when in danger, and guarded for defence. They, too, form social groupings, and at various levels, and with co-operation and division of labour, long and often anticipating our own. They too have shown something of constructive adaptivity, as well as what we call instinct: and if a sheepdog be not intelligent, and careful as well, as to the difficult instructions his shepherd master gives him, and even self-restrained in his wrath with silly sheep, what better understanding of his character can be given? Again birds—often with sociability, courtships and tournaments and admiration of beauty, with lyric song and its appreciation, with co-operation and division of labour in parental care—have they not already some of the finest qualities of human civilisation? With their psychic and organic life and ways, even esthetically productive and constructive ways, even to what we in ourselves call moral—of what else can civilisation be? Is the bower-bird not something of an artist?—the skylark much of poet?—the full-antlered stag a leader? Our domestic animals are not simply man's captives and servants, his slaves and victims; they are also and increasingly his helpers and even friends; and they have largely domesticated him, as from childhood to

chivalry, and from cow-educated Brahmin to lamb-educated "good shepherd". Our anatomy, taxonomy, palæontography and embryography, our laboratory physiology and psychology are all very good; yet the life and soul of biology culminate in ecology in its evolution, and these psychologically as well as organically considered. And all this evolution no doubt selective, towards the fuller and better living association and interaction of human with simpler life. In fact do we not thus see Biology at its best, reaching towards the ideal of a less fallible Adam and Eve, who among their kindly creatures and beside this ever-growing and fascinating tree of knowledge, are also finding that of life; and so with more and more of Paradise Regained?

APPLICATION OF HIGHER FACULTIES.—Now assuming these main higher faculties of Emotion, Ideation, and Imagination, as intelligibly illustrated and outlined, and in relation to the simpler ones, the question next arises of their applications. What use has man made of them in his practical life? Yet so fascinating is the inner life that in well nigh if not all historic civilisations, it has ever given rise to hermitage or to cloister; of which the inmates have forsaken the everyday world of place, work and folk, for these higher joys of the developed spirit, however these may seem but dreams to the plain folk they have left. And though in our day religious emotion, scientific thought, and imaginative creation, are commonly cloistered apart, in church, laboratory and studio, may not this be due to that dissociation of place, work and folk, of environment and organism, of biology and psychology also, into separate studies, which was noted at the outset? For in olden times, from Egyptian or Hindu temple onwards, we find these not only incorporating the knowledge of their time, but carrying its creative art to its highest expressions also.

Yet in the above we are so far anticipating; for even emotion, and thought still more, are often far from taking outward form in deed, as its hermits show, from of old to this day. Yet psychologists agree that thought points and tends to action; and that it may even react banefully on the inner life itself, if not realised, from dream to deed, from meditation to application. Certain it is that with increasing clearness and enlarging interests ideas become emotionalised towards action; and this as collective as may be; and in what is no longer mere Folk-Life, but Polity; and this emotionalised and towards common good, as Etho-Polity. Synthesis in thought thus also tends to collective action—to Synergy; and Imagination combines and pre-figures for our Etho-Polity, in Synergy, the corresponding Achievement—the accomplishments of Deed which it may realise. Here, then, is a new Chord of Life; that of a Psychobiosis, in which the subjective urge and consciousness creates its

objective counterpart. We thus leave the cloister: the City, of our ideal vision, opens before us. We are now out to re-shape the world anew, more near the heart's desire—and hence too often caring little what of the past we shatter.

Here, then, this supreme chord of life and its resultant in Deed; that is, in fullest Life.

		ACHIEVEMENT
	SYNERGY	
↑ (Etho-) POLITY		
EMOTION		
	SYNTHESIS	
		IMAGINATION

And here we might next reason out in detail the completed nine-fold series of thought and Deed, perfected as far as life may allow:—

↑ Tragedy	Rhythm	ACHIEVEMENT
Career	SYNERGY	Success
↕ ETHO-POLITY	Wisdom	Art
EMOTION	Philosophy	Poesy
Doctrine	SYNTHESIS	Design
↓ Symbol	Notation	IMAGINATION

For perfection the inward Poesy must ever take form, as Art; but so Philosophy, when it leaves its cloister, as so rarely, may rise to Wisdom: hence not only the tradition of Israel, but the greatest thought of Hellas if not indeed of humanity, has proclaimed that "it will never be good times for the world till the kings are philosophers, and the philosophers are kings". India has had its royal sages, its raja-rishis, and in these very days is calling for them again. And thus it was, in the best days of old, that Etho-Polity could call forth Wisdom and Art, even if not always the central chord with its Synergy and Achievement.

So true Design (for this is an orderly universe) may achieve Success; and the Career that can synergise is, normally, so far thus justified.

But no life lasts for ever; no career comes to its full. Every life must end, and before final achievement—at best in the midst of this: and this is Tragedy, when the failure is at levels truly high. And does not its subjective correlative—Symbolism—at once

prefigure this and record it? And what next—between Tragedy and Achievement? Here may be Life's supreme Rhythm—life's highest music, ranging, like Beethoven's, between the leaping joy of victory and the funeral march of the hero.

Here, then, is no small conclusion: that from (1) the simplest chord, that of the acts of everyday life—with (2) the facts of its ordinary experience—there may develop not only (3) the deep chord of the inward Life of Thought, but (4) that also of Life in Deed.

Acts	Deeds
Facts	Thoughts

And is it not a strange—and indeed at first an unsought, but now evident result, that in this continuously reasoned presentment of Life, in everyday modern scientific terms, as geographic, economic, anthropological; and as psychological (elemental, and developed), there should thus emerge this unexpected conclusion—that the Greeks of old, whoever else, knew all this before, and had thought it out, to these same conclusions—albeit in their own nobler way?

For our diagram turns out to be that of Parnassus—home of the Nine Muses; and their very names, their significance, and their Symbolisms will be found to answer to the nine squares above, and connect them with those below. And this more and more precisely, as the scheme is studied; not, indeed, without one or two difficulties at first sight, but these easily cleared by a little psychological and social reflection.

Melpomene	Terpsichore	Urania
Calliope	Clio	Thalia
Erato	Polymnia	Euterpe

Here, then, assuredly—even to mathematical probability, let alone to reason—are the Nine Muses of Parnassus, neither less nor more; and as Hesiod recorded them—it would seem from an even then fading tradition, albeit four-score generations ago. Since then at times they have inspired writers, as last at the Renaissance: but too much always as mere literary revivals; till at length they have come to seem too hackneyed for our fresh young poets of to-day.

But none the less, they here reappear in Life and so prove themselves as immortal; not only as the source of inspiration of all poets, past, present, and to come, but the very genii of will, the inspiration of every worthy deed. And they come to all peoples, simplest as well as highest: the first clue to this recovery came, indeed, not from musings in Athens or at Olympia, from dreamings at Sunium or on

Pentelicus, but from the simple dances of the Australians, from the flower-crowned Hawaiian maidens of Cook's Voyage, and again from the varied moods of the songs and tales of Highland Ceilidhs. Everywhere then we may find or recall them: they are the nine-fold Soul of Life.

Still it is the Greeks, above all other children of men, and despite all their faults, who have been most complete exemplars; for all Nine Muses came most fully to them. Hence theirs not only the fullest chord of the Inner Life, emotional, intellectual, imaginative, as in Plato perhaps above all; yet he only first among peers. For Hellas was creative at once of morals and philosophy, of esthetics and logic, and of the beginnings of every one of our modern sciences; and also in every way giving fresh, rich and full expression of all their nine-fold complex in the active life of Deed. Thus it was that beyond town and school, beyond even the retreat, or porch, or symposium of thought, the Greeks realised the City—and least imperfectly of all men—the City founded on sound agriculture and craftsmanship, and this rising to initiative and perfection in each and all of the material arts—architecture, sculpture, painting. So, too, their life blossomed into the dramatic arts—music in all its moods, with dance no less fully expressive, drama to this day supreme. All because founded in comprehensive thought; and thence realised in citizenship.

The application of the present method to other cultures, and through West and East alike, will be found to yield no less vital interpretations.

To go so far beyond everyday biology and psychology has been necessary, even were it only to meet Wallace's difficulty; moreover, if this be a true outline of the evolutionary process in nature's highest species, why and how should we stop short?

And just as, on the highest levels of animal social evolution, we have cited suggestions and premonitions of the above results: so now we may look further into such developments. Maeterlinck's interpretations of his bees can hardly but have seemed going rather too far for sober natural history and its comparative psychology: yet we may look for an interpretation of the bee-folk and their ways going further still, in terms of this whole life-theory. This was, indeed, worked out in detail many years ago (for this theory has been long considered) by our late friend, Miss J. W. Home, one of those admirable psychologist-teachers whose sympathetic insight and intuition surpass those of most men, if not all. The general correspondence with our above outline of human evolution at its highest was broadly clear. If so, may not this whole theory and presentment of life's process and progress be applied more extensively, in both directions?—i.e. (1) backwards, into simpler life, and

(2) onwards, to fuller interpretation of human progress towards its best, and even of incitement to it anew, for the individual and his community alike? And if so, is not this another way of evocation of our latent Supermen—and of careers worthy of them?

THE ORIGIN OF EVILS.—Here surely we see the most portentous of doors for trial of this simple and insignificant-looking Life-Key. What vast field for thought has been more stimulating to man in every way, yet what more resisting and perplexing—even to resignation or despair? Yet what can more clamantly call for renewed endeavour? Yet after all these long endeavours of thought, and that of all kinds throughout history, efforts of all kinds as well, we have no adequate science or philosophy of evils, nor yet any consistent policy of dealing with them. Here, as in so many cases, the initiative of thought, and of active policy alike, must be credited to the historic religions; yet neither their doctrines of evil and its origins, nor yet their methods and modes of dealing with them have satisfied the world; so that medicine, law, and other agencies, have to take their own course. Yet with still too little to show; too often, indeed, with mere broom-sweeping against tide and storm.

Yet recall the old tale of the prisoner in his dark cell, with closed massive door, which in active moments he pressed and shook with all his might, yet for long years in vain. At last, peeping under the door, he noticed a trifling key lying on the ground below the huge lock, which his jailor had dropped. So out he came, to liberty and what remained of life. Why not then try this Life-Key, and before too late? And even at simplest, as he did (Pwf).

One thing about evils is manifest from the first: they may be positive or negative. So begin with the latter, as less difficult. To have no Place is to be a landless and houseless wanderer. To have no Work is unemployment, a sore evil, but to have no Folk, as neglected orphan or outcast, is harshest fate of all three. Yet these may only too readily unite, so in Poverty at extreme, in hunger and rags, destitution and starvation and neglect by all.

But positively bad Place, say bad housing, is in dirt and misery, and involves disease; and bad Work leads to speedy death: witness, taking these together, the death-rates of the early industrial age in Britain, and now repeated, as Indian cities enter on its example. But bad Folk—"bad company"—does not that readily become worst of all? And when we combine all these, see how readily the tramp, and now too many of the sedentary unemployed as well, become unemployable.

Next consider the related psychological side. It is a hard fate to lack Senses, to be blind or deaf; yet even in losing life, as thus so easy, these are innocent of blame. Without Work, how gain Experience enough for employment? Without our own Folk, we may still

elicit some Feeling from others. But to have senses, yet fail in right use of them, is the way of mistake and accident, even to grievous and terrible disaster. And the like from inexperience. But while to lack feeling for others is only too easy in bad circumstances, when also in bad company we too readily come to perversions of feeling, with which worse evils than any before too readily open and advance.

To lack Imagination is our common failing, essentially arising from ill-nourished sense-experience, feeling and emotion; and it is often emphasised by school "copy". To lack in Ideation has a kindred explanation in the black art of mis-instruction established as "cram"; while the lack of Co-Emotion is in the measure of our starved individualism, so often standardised by the same; yet often too by its would-be arousal, from once emotioned sources, by the teacher, but now repugnant to the scholar or student (as "jaw"—or even "pi-jaw!"). The way of education so-called is still paved with these errors of good intention, which depress and repress the growth of mind; however enforced with honest desire of arousing and enriching it; as per so much of our Education Codes, and Examination Regulations.

But even the most repressed imagination cannot but work a little, so it readily goes wrong, into temptations, and these imaging—unworthily—natural desires, which ideate into needs, and press towards wrong action. And this the more if mis-emotioned, and this worst of all in bad company, since more easily soured to cynicism and readily embittered to hate.

All this might readily be followed further, to deepest evils and their consequences in detail. This central outline, to the bio-sociology of evils, can next be worked out around our initial life-graph. Outside normal life's Acts and Facts, its Thoughts and Deeds, we may place the negative evils to its left and right, and the positive above and below; with their mutual compoundings to yet worse evils in the spaces diagonally between. Thus the diagram shows outside the simplest range, of mere mistake, weakness or temptation, two other and parallel series of evils, "venial and mortal". These three ranges in all are what were ruled and scourged by the three Greek Furies. Stranger still, here also appear in vivid renewal the circles of Dante's Inferno, seen, as he said, "in his City"; and much as he worked them out on his models and graphs, as shown in a well-known portrait. Indeed, beyond these, as we logically work on, to consider treatment, our next resultant series of spacings correspond to the circles of the Purgatorio; and beyond these again come these of the Paradiso! These are all quite unsuspected and unsought coincidences of mytho-poetic presentments with modern ones; yet rational too, showing how the bio-social thought has anticipated ours. Our ninefold graph of Life may also recall that of the "Nine Stone Circles", over Europe and beyond. At any rate,

it turns out to have been handed down by Pythagoreans, all the way to medieval alchemists and magicians, one of whom explains its logical application, exactly anticipating ours, "to any triad", be this mathematical or physical, philosophical and theological. Again, our two directions of reading the life-diagram (beginning with Pwf or with Fwp) next surprise us as being exactly those of the world-wide (yet now especially Eastern) ways of life-interpretation and life-direction—signs so frequent on Eastern carpets, as the reader may have noticed. Chinese characters in origins also confirm and anticipate our graph-making. And finally a learned friend, at once mathematician, chess-player, and scholar, was surprised by the resemblance of this life-graphic and its moves and results to an early form of chess, traditionally invented by the magi of Persia "to teach their young king the art of life". Such excursions among ancient notations and symbols have only arisen after the devising and use of all such graphics as the present, which have thus been in no respect suggested, nor even in any way modified, by them. Such coincidences surely show that ancient thought was often more vital and evolutionary than it has seemed since their graphic techniques and their meanings were lost sight of; or even suppressed, as savouring of magic and wizardry, occultism and heresy.

Treatments of Evils.—If, however, all these hydra-headed evils be thus seen in terms of the life they injure, what of their treatment, towards abatement; and why not even towards purgation? Take first the evils arising in our first square, of everyday Acts (Pwf). Poverty has always made first appeal, and so had alms from the charitable; and its disease has ever had generous treatment from the physician. Ignorance, and worse evils of the square of sense-experience-feeling have been struggled with by parents and teachers. Vice, with its many aberrations of imagination-ideation-emotion, has been especially combated by moralists, clergies, and saints. Crimes, from sentinel's thoughtless sleep on his post, and through graver misdeeds, to utmost treason, have all been dealt with by police and by law. But as yet all alike far from successfully—why? Is it not largely because all these four classes of would-be reformers or punishers have themselves lacked and fallen short of needed unison in thought and action on life? For see what better results are now arising, and at many points over the world, from incipient co-operations; and these from the psychologic side first, so notably by our psychological and biological colleagues, the mental physicians; who are so fully dealing with their self-centred, and often more or less morally vitiated, patients and restoring them to saner views of life and duty, thus not only preventing them from further ill-doings, but often restoring them to normal health, with its everyday life-duties and common sense anew. So, too, with the

advancing progress of prisons; and the increasing reclamation, and even rehabilitation, of their prisoners. Increasing numbers of social workers are now on right lines; and with their co-social advances, the needed techniques begin to appear; by which our present charities and hygienic endeavours, our educational institutions and their workings, our religious organisations, and their spiritual and social efforts, are being increasingly unified, and with encouraging beginnings of influence on bureaucracies and statesmen as well.

Hence this correlation of Evils—above only outlined and suggested, since obviously needing development into a volume, and with compounding to the needed elaborate charting—may be of interest, and even use, to whoever will take the trouble to give it fair trial, and patiently work out its many squares.

ORGANIC AND PSYCHIC INTERRELATIONS?—The functioning of our brain or brain cell-groups is not easily imaged; and still less can we express our mental functioning in other terms than its own, as of sense, experience and feeling; of emotion, ideation and imagery; of desire and will. And though certain brain-localisations are demonstrated, as of the speech-centre, do we thereby get any nearer a real understanding how what we call brain and what we call mind are really working together, however much we are compelled to believe it? The brain structure and functioning still remains as one sort of thing, and the psyche which seems by turns so recipient, yet so initiative, still seems another. Thus biologist and psychologist, however separately richer in experience and understanding than when they began their inquiries, have not really got much, if at all, beyond the simple doctrine of distinctness of body from mind or soul, which was taught them in early years. Did simplest humanity, however, realise any such separations? Or are our modern children, before they absorb this from the social atmosphere around them, any more troubled by it than are animals and their young? If so, may not this feeling of separateness of mind and body be but a product of our particular phase of evolution; and thus more to be explained on lines of social development, historic and even prehistoric, than on simpler life-levels? In the higher animal, though we cannot compare notes with it, we recognise an organic life essentially similar to our own; and its behaviour compels us to appreciate a psychic life fundamentally akin also; and this the more as comparative psychology advances. But though Descartes' extreme view of our dog-friend as a mere automaton can hardly but suggest that he can never have had one, we thus learn not to exaggerate its humanity; yet also that much of our ordinary life is nearer the canine level than older psychologists had realised. Our view of the animal, with its bodily and mental life more closely in simple unison than ours, and still more that of lower organisms, seems nearer being

monistic, than for ourselves. Yet in sleep at its fullest and deepest, in which our consciousness has subsided into latency, do we not return also to the deepest levels of our organic origins; so is not the monistic view more nearly approachable here? The extreme dualism of mind and body in our most conscious and active hours, seems here to have subsided into a silent and passive harmony. Again, though we speak of sleep and waking, each as a whole, most of our bodily organs never wake to consciousness at all, unless, indeed, in pain, and though teeth are only too capable of this, their nervous supply explains it: while hairs and finger-nails are similarly only associated with sensitiveness at the like root-level. Yet that hair has a certain part in the general consensus and coenasthesia of the organism, many since Samson have experienced from its shearing; for emotional intensity and its energy outflow seem thus lowered, indeed in some severely so. The intensest of organic vitality, that of birds, is accompanied with their higher differentiations of hair structures, first to down, and then to feather: whereas the densely consolidated and passive epidermic crusts we call scales are appropriate to the cold-blooded reptiles. Yet the comparative nudity of our skin, however, is an obvious advantage as regards sensitiveness, and thus not only to touch, but temperature, etc. And as regards the epidermis, the development not only of the sense-organs, but of the central nervous system itself, from its originative embryonic surface-layer seems in every way natural.

In short then, the organic and psychic life have not the sharpness and distinctness of separation ascribed to them by the older psychologists. The normal functioning of the sympathetic nervous system, of involuntary muscle, the life of cartilage and bone, are all unconscious to us; yet they are capable of giving us pain; so we cannot deny them something of psychosis, however deeply dormant and the like for all processes of life and development. So in all manner of ways we are pressed to the view of biosis and psychosis as everywhere associated throughout living nature. Long though the ascent may have been from Protozoa to ourselves as at least incipient Psychozoa, we have each gone through it in development; and (dreams apart) we practically recapitulate much of this every morning and reverse it in falling asleep every night, so far anticipating the normal and tranquil decline and death of old age; for what older and truer observation of that than its gently falling asleep. Normally, then, it is but disease and pain which are feared, rather than death, which may even normally be welcomed as repose.

Here now a criticism of contemporary psychology, at any rate as we and other working biologists see it (or, as some may still say, fail to see it). We confess to be but seldom attracted either by its experimental or its intellectualistic papers, which often seem to us too elaborately mechanistic, or too abstractly removed from our

simpler observation of life. We can, of course, see the interest of (say) a maze-experiment, on one hand; and on the other we would fain know more of sensing, experiencing, feeling and conating, and what not; and even follow, as from Sherrington's elaborate elucidations of the reflex action, onwards to what we imagine may be something like Herbert Spencer's upbuilding of his Principles of Psychology, upon the contemporary spiral or other sweep of ascent. We see, too, the interest as well as the practical value of (say) Munsterberg's testings for tram-drivers, and of the like developments for aviators: but we feel dubious when Behaviourism fruits into fresh advertising devices. And yet more when American chemical employers, as in their recent labour-troubles, call in the psychologist to investigate their "turn-over", and to verify experimentally—what surely everybody knew already—that the leaders are more intelligent than the led, and those who ignore their appeals are apt to be least so—and when his prescription is next brought over—and by the leading American representative to the recent British Congress of Chemical Industry, and apparently with their approval—as "Select stupidity, and train it!" For here is Robot-breeding outspokenly proposed, and as their new form of quasi-eugenic policy, for application to the masses.

In such applications of psychologic or other sciences, the scientific mind is no doubt active and alert, just as for the current "improvement" of war-gases; yet are not most of us old-fashioned enough to prefer following in such directions as those of Pasteur's and Lister's life-aiding labours, and of kindred ones in progress at this day? We cannot but maintain that science and its arts are for life, and not these for bodily death or for mind degradation; and hence we look for the increasing moral rebound of all women and men of good will against such prostitutions of knowledge and of power. And even confidently for their approaching and definite eliminative selection, with the advance of evolutionary thought and spirit, throughout their correspondingly advancing world.

As naturalists, we have no occasion to make painful experiments on animals, though for teaching purposes we have been responsible for deaths, albeit with due economy of these; yet we cannot but approve at least of many, if not all experiments now being made under the Vivisection Act, since essentially in the interest of physiology towards medicine, and preferable to human tests, as for new remedies, etc. Yet, with the great majority of such experimental workers, we accept and approve that this should be done under due regulation and its inspection: for we know that the excitement of the public which invoked these was not entirely without foundation, since there are records of painful experiments we cannot but think futile in conception, and even of certain ones more or less approaching the sadistic; and which afforded the main

grounds for protest. Hence, since such moral rebound and public regulation have arisen as to animal life, why not yet more for human life, and for community life above all?

Yet such can be but steps towards that general re-moralisation, of which more than evolutionists see encouraging beginnings. Social aim may surely be as stimulating to each and every science as to invention and to the fine arts, to medicine, and to education, as to social and moral progress. And is it not when these are deficient that we have scientific elaborations tending to futility, and inventions and devices of trivial attractiveness? Has it not been such laxity of the scientific and the practical spirit, in so-called peace, that has ever made room for the sinister researches and the strenuous applications of the war-world, up to its now appalling potentialities?

Without yet fuller place for the psychic side and aspect of life, our views of the developmental process and the evolutionary alike remain too naively mechanistic to be fully satisfying. It is, of course, intellectually and practically necessary, at once rational and right, to carry our physical lines of explanation as far as may be, and to frame and test hypotheses for carrying them further still; else we should fall again, as so many have fallen before, into opposing the advance of each "legitimate materialism" of the preliminary sciences, by futile abstractions, unjustifiable transcendentalisms. Inorganic Nature's protean beauty of snow-crystals needs neither internal psyche nor external design to explain them—any more than does their massing into flakes as they fall into drifts as the wind blows, or into ice as they gravitate and cohere and freeze anew to flow as glacier, melt into stream-source, or break off as mighty icebergs at once a glory and a terror of the ocean. We do and must carry our conceptions of mechanical and physical processes into organic development for all they can give us of intelligibility in detail, as (say) for the division of cells with increased volume, or for the growth-impelled symmetric lateral uprisings to form the primitive groove so manifest in the early development of the chick; and so on, as best we can, to its very completion. Yet in all this there remains unexplained that orderly procession and co-ordination of life-events towards unity in form and function, which is indeed even more impressive in embryonic life than in the adult. It was obviously too abstract and too externalist to invoke here, as in former generations, an "Archaeus", a "Vital Force", or the like; yet the continuous and progressive co-ordination of active growth and manifold differentiation, yet with harmonisation of all differentiations into unity of form and function, is not really fully conceivable in purely mechanistic imagery. It leaves us with no alternative but dimly to visualise a corresponding incipience and progress of what we soon begin to see as neural development and control, so

far incipiently and progressively psychologic in its nature accordingly, and interacting with the organic process throughout. It is no doubt incongenial, since well nigh hopelessly difficult, to speak of each step in development as accompanied, and even unified with help of a "mind" that is no more completely there than is the finished "body"; yet if biosis and psychosis be not there, and in co-ordinated interaction from the initial ovum to its completed outcome, how and when can they ever get together and work together?

In our necessarily external observation and of bodily developments alone, in animals and even plants, do we not too easily forget that we are thus not advancing upon, but lapsing from our child wonder as something of mind appears in the young baby; and since this has come by way of parents, and from ancestors, it can surely never have been completely missing, or utterly functionless.

Moreover, in any and every review of Life-development, from pre-Protozoon to Man, with its branchings well nigh innumerable, what is after all the main characteristic?—and outcome? Surely that of psychic evolution, however convenient we find it to state and trace this in neural, cerebral, and other morphological and physiological terms. Even if we seek to content ourselves with psychology in its most reduced terms, as of the Epi-phenomenalism of Huxley, or of Psycho-parallelism with others, there it is; albeit in these sterile forms yielding no light either upon organic development or its own; whereas in our concept of Interaction, we see its rhythmic progress, of Bio-psychosis and Psycho-biosis, as the central and unifying life-process throughout individual development and racial evolution alike. Heredity, Variation, and so on, are thus not merely biologic terms, but carry psychologic meaning as well; for what way is there out of that hidden—yet deeply manifest—harmony of Being and Becoming, save by postulating that of one side and aspect of life with the other? If not, we should have no general scientific term to include even our own life outside inorganic Nature, for non-life, for biology and psychology alike, is termed Death.

Is it necessary to add a final illustration? What better than the familiar one of any book before our eyes. Say, then, this one—an obviously material object, plainly admitting of clear and continuous mechanistic explanation, from paper- and ink-makers, printers, binders, publishers, and booksellers in turn, and before that from our own pens and ink, and hand-muscles worked by nerves from motor brain-centres. And yet none the less continuously (before these so far mechanical-looking processes, yet each and all psychologic too—and ethico-social as well)—an intimately mingled product of two long-associated minds as well as brains, and each of varied acquirement and reflection, alike on personal nature-knowledge and on that of others, yet so far co-ordinated by prolonged co-operation and mutual criticism, towards such unity as it has. A unity obvi-

ously imperfectly evolved; yet which may thereby all the more stimulate younger successors to supersede it, by telling their tale of Life anew from their own higher levels, both of personal development and of evolutionary advance, biological and psychological together.

DETERMINISM OR FREEDOM FOR GEOGRAPHER AND PHILOSOPHER.—Having one day a visit from these two friends, each long acquainted, though not in studies, we yet introduced them, but the former as "Professor of Philosophy", and the latter as "a possible student of Geography". To them, as to others standing by, this seemed first a slip of the tongue, and next a rather obscure joke; so explanation was needed. For the philosopher, like his fellows, cannot but puzzle between determinism or freedom, in the abstract. Yet has he not his particular bias largely settled for him, sub-consciously, by his own life-experience of the world and the way he has lived in it—in the broad sense then, by his general and social geography, even though he does not realise or readily admit this. The concrete geographer, on the other hand, though seldom if ever giving a thought to that philosophic question in the abstract, concretely knows it; and clearly, however sub-consciously, from his own direct survey of the world. Thus he knows Holland, as originally the worst environment for man in Europe, not simply with its poor moors and sands, but with great rivers yearly flooding its plains, and with sea often breaking in as well: witness its great disaster, so late as the fourteenth century—the in-coming of the Zuyder Zee, drowning towns and villages beyond number. Here was Nature's Determinism, and at its harshest; yet since for ages the Dutch have been steadily banking in their rivers and dyking out the sea, they now live safely and well, even deep below tide-levels; and are even reclaiming the Zuyder Zee itself for half a million prosperous farm-folk and villagers in the generation after next. Here then is victory of human freedom over Nature's determinism; yet at the price of vigilance, even to *levée en masse*, when the tocsin warns that a dyke is in risk of breach. From this obvious case of Holland, we may now pass to Switzerland, with its difficult alpine environment, also so well taken in hand by man; and thence to any and every country, as circumstances—or choice—may direct. Social Geography, as in Elisée and Paul Reclus's *L'Homme et la Terre*, and other works of social geographers, here affords suggestive material. Yet it is most educative also to make our own surveys, with photographs and pictures, maps, plans, and graphic outlines; and next also such interpretative chartings as we may. We thus see that the geographer (however much like Monsieur Jourdain as regards conscious philosophy) has the sounder view of this great old philosophic controversy; since he is now at once concrete and relativist, and with

physical and biological knowledge underlying social. After studying so many systems of philosophy, each more or less deterministic or libertarian, which have grown and flowered and faded, the student may often despair of clear solution; yet here in real life it is clearing up before us. And if so, why not set about clearing it up more fully? The abstract philosophers have been too much but tilting in the ancient quarrel of the gold or silver shield, which was neither, yet both; since silvered on one side, gilded on the other.

On the whole, however, our interpretation of Holland may seem so far deterministic; for each sea-dyke becomes a new determinant, impeding further reclamation from the sea. Yet who can say that Holland may not be extended yet further? Soundings and other surveys may show further extension possible on sand-banks, yet impracticable in the deeps between: so that limitation of extension, and freedom for extension, are each relative so far, though the Ocean ultimately determines the limit. Yet this being so, the Dutch long ago conquered that, as seafarers, to foremost proportional record among all nations, and even with a period of veritable national dominance. Yet even this was limited by others in turn; so it may still appear that Holland is but a limited little country and people after all. But what of their culture-achievements—as from agriculture to crafts and arts; from boat and shipbuilding to their world-masters of painting, like Rembrandt, Hals, and Rubens—or from learning to literature, with Erasmus and more; and from custom to world-justice with Grotius. And so too in science; in fact in many respects showing potentialities, and expressions of these, which go far to justify high expectations for Holland and hopes for humanity, as more than the Hague Court is there to show. And when this is true of one small people, what of others? What, too, of the greater ones—and in their incipient efforts towards harmony?

We see that however determinism may limit life on physical or even organic levels, the psychological and social life may be thereby all the more pressed on to higher freedom of effort beyond. But do not even achievements again become limits? Undeniably, yet never absolute ones.

Thus, instead of a simple acceptance of either determinist or libertarian conclusions, we see in their perpetual alternation, on heightening levels, a main factor of true progress, though granting that progress may at times be arrested—or even too easily go the wrong way. But even here the Dutch national dyke-vigilance comes in, as exemplary principle; the spirit thus controlling the environmental life-adjustment, even when and where it cannot at the time transcend it.

Through history we might trace this contrast of determinism and freedom; and indeed as one of its ever-recurrent ideas; in fact, throughout the varied children of men. Among these the philo-

sophers have been the most conscious, educationalists the most clear-voiced, and the theologians, idealists and poets most widely listened to. Thence returning to current biology, and with type-illustration for that, it is plain enough that neither Lamarck, Neo-Lamarckians, nor Bergsonians of to-day have ever thought of ranging themselves under Luther's theology, of salvation by faith freely open to all; nor yet Weismann, Neo-Darwinians, and Eugenists under Calvin's sterner view of fore-ordination. Yet each and all of these doctrines is of life and its realisation; and it simply needs a little reflection to see the essential correspondence of those above-paired. And by help of their antithesis, is not a fresh and fuller synthesis emerging; yet with counter-syntheses persistent, by turns the bio-psychological, as more determinist, and the psycho-biological, as more libertarian? And with something of all this even in simpler life than our own? Else how should it arise in us, had it nothing to arise from?

SUMMARY AND APPLICATIONS.—What now are the results from this Life-discussion so far? What uses of all this? Separately its stages are clear and simply realised, even focussed to graphic presentment. In every science empirical knowledge is valued for the rational ideas it can yield; and these towards larger unities, into which they can be co-ordinated. So when at the outset each of three sciences—geography, economics, and anthropology—hitherto treated apart, and each by its own methods, even without adequate agreement on these among its cultivators—are shown capable not only of more orderly treatment, each in harmony with the neighbouring studies, and all unified into social science and in full harmony with evolutionary biology, this may fairly claim to be a definite advance.

Nor does this correlation end with these three concrete sub-sciences of sociology, as this must claim them. First the elements of psychology have been integrated with these, and they with it; with gain in clearness and fullness of each and all from this further unity. Next from this elementary psychology, we have passed to its deeper and wider fields; and these have been more clearly outlined accordingly. For in this cloister of the inward life, folk-feelings are seen and felt as transmuted to social emotions and ideals. Empiric work-experiences are clarified into ideas, and these organised into the rational sciences. These are advanced towards synthesis; and next our external sense- and place-impressions yield materials for creation of individual and collective imagery. In this complex world of inward life, these three main elements, too often separate, there as idealistic, here as scientific, or in others as imaginative—are seen as normally uniting into a single chord of inner life, and this harmonious to that simplest material life-activity with which we started. Nor does this synthetic presentment end in the

cloistered world of thought. On the contrary, it becomes plain how we may and do return from it, to the objective world; yet no longer simply acceptant of the place, work, and folk with which we set out; but now modifying, or even reshaping, these, as far as may be; and that in terms of our inwardly emotioned discernment and vision. Our ideals thus attain outward form and expression; they re-group and re-associate all who share our ideal, whatever that be, into some fresh form of social organisation, great or small. So our initial work-experience, now ideated and theorised as science, impels to application, even upon some fresh line; yet this no longer so externally conditioned, as mere act, but inwardly clarified towards realisation, and thus in collective or individual energy of deed. Our sense-acquired, yet thence transmuted, mental imagery thus finds outward embodiment, be this in victory, in art, or other achievement. But only in the measure and harmony between these three inward elements and impulses can be their effective realisation. This fresh chord of life thus attains its intensest and highest expression—and hence passes beyond individual effort; it rises to Etho-polity, with its Synergy, and its Achievement. Have we not all been impressed by the high measure in which our recent antagonists in war so vigorously organised this unison? We suffered much from such effectively unified ambition and endeavour during long years of war, with its well organised attacks well nigh overpowering us. Yet in its last period, that potent synergy was dramatically reversed, partly no doubt by incipient exhaustion, yet also by more fully allied unison of these same psychologic elements, applied with yet fuller intensity, and thus to ultimate victory. So why not now a yet fuller arousal of the ardour and devotion of youth, uniting anew its emotional, intellectual and imaginative powers, and these turned towards deeper and higher social achievements, with generous rivalry in the arts of true peace, at once reconstructive and evolutionary? Are not many elements of this already stirring over the world, and but needing fuller equipment, organisation, and leadership in their turn?

And if so, may not—indeed must not—such experimental developments be pregnant of further thought as well? *Vivendo Discimus*. And so on, indefinitely: for Life evolves through Living; so from Act and Fact to Thought and Deed; and then again modifying Acts and Facts: (Discendo Vivimus!) hence more capable of rise to new Thoughts; whence Deeds anew. And so on (cf. p. 1413). Is not this the process of Social Evolution at its best? (And, if so, what of its incipience, from, and in, organic life and Development as well?)

APPENDICES

APPENDIX I

GREAT EVENTS IN BIOLOGY

THE foundation-stones of the science were laid by Aristotle (384–322 B.C.), who began to classify and dissect, who understood what is meant by homology and by correlation, who saw the beating heart in the developing chick-embryo, and had a glimpse of the deep uniformity of development in all animals. But perhaps his greatest contribution, long of being generally imitated, was his insistence on observation as antecedent to reflection. Yet centuries passed before he found an outstanding successor in Galen (A.D. 131–201), who dissected much, and may be called the first experimental physiologist. In spite of an occasional irrepressible observer, the letter of Aristotle was persistently stronger than his spirit, as far as biology was concerned; and it was not till the sixteenth century that the fetters were broken. The Belgian anatomist, Andreas Vesalius (1514–64), has been well called "the emancipator of biology from the traditions of the ancients", for he insisted on an independent scrutiny of facts. Another even greater initiator was William Harvey (1578–1657), whose *De Motu Cordis et Sanguinis* was published in 1628. It was not merely that he demonstrated what his precursors and anticipators (like Servetus and others) had hinted at, the circulation of the blood; his larger importance was in showing how the flow was sustained. This was also the epoch-making first proof that some processes in the living body may be in some measure interpreted in terms of mechanics. It was the first instance of a "legitimate materialism" in biology. Moreover, although the axiom "*omne vivum ex ovo*" was not Harvey's, he had a prescient conviction that "all animals are in some sort produced from eggs", and laid another foundation-stone in declaring that practically every organism begins its individual life from an apparently simple primordium in which "no part of the future organism exists *de facto*, but all parts inhere *in potentia*". And yet, as Huxley points out, Harvey believed in spontaneous generation as firmly as Aristotle did. It seems fair to rank the Italian Redi (1626–98) as a foundation-layer, since he was foremost in proving experimentally that spontaneous generation did not occur in the cases where this had been alleged. But the heresy of abiogenesis has died hard. Even Pasteur and Tyndall hardly gave it its death-blow.

Another fundamental step is associated with the invention of the compound microscope, shared in by Galileo, about 1610, for this in

time began to alter the whole aspect of the long embryonic science of living things. It was not merely that a new world of minute organisms was revealed; it was not merely that what had seemed macroscopically simple was shown to be microscopically intricate; the far-reaching advance was rather that many vital phenomena became in a new way intelligible. Visible processes which had seemed almost magical in their occurrence were made intelligible in terms of the previously invisible. Thus although Harvey had demonstrated the passage of the blood from the arteries to the veins, he had not actually seen that passage, since it is effected by the invisible network of capillaries. This, so well observed in the web of a frog's foot, was demonstrated in the frog's lung by Malpighi (1628–1694), born in the year of the publication of Harvey's great book. Similarly an insect's life is quite unintelligible until the air-tubes or tracheæ are recognised as such; and though the larger ones are readily seen with the unaided eye in a big beetle, this is not possible in smaller types; and in any case the significant fact is the intricate system of previously invisible branching tubes by which air is carried to every hole and corner of the body. Here the historian would also recall the work of Swammerdam (1637–80). It gradually became possible to discover the young stages of organisms, including the mysteriously intruded parasites; and here great honour is due to the memory of Leeuwenhoek (1632–1723), who discovered not merely Infusorians, but Bacteria, and sperm-cells. With this brief introduction we must now abandon all attempt at narrative, and be content with an enumeration of what may be regarded as some of the most important of the great events in the subsequent history of biology.

Linnæus (1707–78) included Plants and Animals under the common title Organisata, and laid the foundations of Taxonomy.

Cuvier (1769–1832) laid emphasis on the correlation of organs in the body, and laid the foundations of Comparative Anatomy, in which, for the first time, he began to do justice to fossils.

Of far-reaching influence was the idea of unity of plan underlying great series of organic structures—the idea of homologies which was for a time dominant in Goethe's versatile mind. For he was one of the first to have a vivid realisation of the higher plant as an axis with leafy outgrowths, protean in their "metamorphosis" into all manner of varied leaf-forms, and even into all parts of the flower—sepals and petals, stamens and carpels alike. He made his partial mistakes, no doubt, as with his interpretation of the mammalian skull as equivalent to a series of vertebræ, but he had a vivid interpretative insight into unity of structure. To Goethe the term "morphology" is due—in itself a great contribution to science, and he is also to be remembered and studied as a philosophico-poetical evolutionist—right in idea, even when his facts were wrong.

Lavoisier (1743–94), the main founder of modern chemistry, first made it clear, with the help of Priestley's discovery (or, rather, re-discovery) of oxygen, that living always involves a process of combustion or oxidation, and thus contributed one of the most fundamental ideas and initiatives of physiology.

After Stephen Hales's (1677–1761) great initiative of vegetable physiology and Priestley's (1733–1804) discovery of oxygen, and the hardly less important steps taken by Ingenhousz (1730–99) and De Saussure (1767–1845), there began to be some understanding of photosynthesis, the most important vital process of the world, in which green plants, using the energy of red-orange rays, break up carbon dioxide, liberating oxygen, and build up carbon compounds, such as sugars.

Liebig (1803–73) was pre-eminent in demonstrating the circulation of matter, a fact of the deepest importance in biology. He showed how various elements, such as carbon and nitrogen, iron and phosphorus, are continually passing through a cycle of diverse combinations, entering successively into the composition of very varied molecules, and taking part in very different organic embodiments or incarnations.

In 1838–39 Schwann and Schleiden formulated the Cell-Theory, Goodsir and Virchow being contemporary in apprehension, and Lamarck a notable anticipator. The Cell-Theory (or better Cell-Doctrine) includes three propositions: (1) All organisms have a cellular structure, being either single cells (Protophytes and Protozoa), or collocations of cells and modifications of cells (multicellular plants and animals); (2) every multicellular organism, reproduced in the ordinary way, begins its life as a fertilised egg-cell, and develops by its continued division, whence multiplication and differentiation of cells; (3) the life of the multicellular organism is the sum of the activities of the component cells—and yet something more, since there is an integration which makes the behaviour of the whole more than the additive sum of the activities of all the component parts.

The Russo-German investigator, Karl Ernst von Baer (1792–1876), must be ranked as the founder of Comparative Embryology. He elucidated the cleavage of the egg (including the mammal's), the formation of germinal layers, and the gradualness of embryonic development. He was also one of the first to show that in a general way, in organogenesis in particular, the individual development tends to be a condensed recapitulation of the racial evolution.

To be linked with the Cell-Theory was a step associated with the names of Dujardin, Von Mohl, Max Schultze, and Cohn, and dating from about the middle of the nineteenth century—the extension of scrutiny beyond the cell to its living matter or protoplasm. This implied what Sir Michael Foster called "a change of front" in biology.

Another milestone was Wöhler's synthesis of urea in 1828, for the building up of this characteristic organic substance from simple inorganic materials made the first breach in the blockading wall between what goes on in non-living Nature and what goes on in the living body. It was a first—yet in principle decisive—shock to the doctrine that organic substances could not be made except by organisms; and it was the beginning of that brilliant succession of synthetic achievements which have yielded not only sugars and alcohols, but such complex substances as salicylic acid, indigo, madder, adrenalin, and thyroxin. In the synthesis of amino-acids the creative biochemist is drawing near to the artificial production of proteins—hammering at the gates of Life's citadel. But apart from the synthetic triumphs which followed, and still follow, Wöhler's great step, there was the blazing of a new trail. The products and processes of the living body were no longer in a preserve for the physiologist; they were illumined by the analytic and synthetic methods of the biochemist.

With the name of Claude Bernard (1813–1878) several great steps are associated. He established experimental physiology on a firm footing; he discovered the glycogenic function of the liver; he was one of the far-off anticipators of the hormone-producing rôle of the ductless glands. But it is mainly to him that there should be traced the illuminating idea of the twofold aspect of the normal chemical routine of the body, which is at once or by turns constructive and disruptive, up-building and down-breaking, winding-up and running-down, storing and spending. In more technical language he distinguished in the metabolism of the organism its two main processes—anabolism and katabolism, and thus generalised the chemico-physical aspect of the moving equilibrium of life.

Not less important for the general biological outlook was Claude Bernard's *Phénomènes de la Vie communs aux Animaux et aux Végétaux* (1878), for it brought into clearness and prominence the fundamental similarity in the main vital processes (photosynthesis excepted) in the two apparently contrasted sub-kingdoms of Organisata. As a recent worthy appendix to this classic may be ranked the ingenious investigations of Sir Jagadis Chunder Bose on the sensitiveness and other animal-like features of plants.

Man's pollination of the date-palm goes back to remote antiquity, but a scientific appreciation of the sexes of plants did not come till near the end of the seventeenth century, when Camerarius proved that pollen is usually indispensable, if there are to be fertile seeds. This was a great step towards a deeper recognition of the unity of plant and animal life, and what was at first somewhat crude in expression was elaborated into the demonstration of an intimate correspondence between the reproductive phenomena of plants and animals.

We give prominence, which some may perhaps regard as exaggerated, to Steenstrup's elucidation of "alternation of generations" in animals, especially in Hydroids and Trematodes. It may be defined as the alternate occurrence in one life-cycle of two or more different forms differently produced. Thus a practically asexual Campanularian Hydroid colony, very plant-like in appearance, buds off free-swimming Medusoids which produce eggs and sperms. The fertilised eggs develop into free-swimming larvæ, which eventually settle down and begin the asexual budding which results in a zoophyte colony. Of this discovery there had been anticipations, such as the poet Chamisso's observation, early in the nineteenth century, of the alternation of generations in the remarkable free-swimming Tunicate called Salpa, but the generalisation of a large number of other puzzling phenomena as kindred ones was to Steenstrup's credit. But part of the reason for giving prominence to alternation of generations is because in Hofmeister's hands (1849–51) the idea served to unify in a new and luminous way the life-history of the long series of plants from liverworts to flowers. By a brilliant series of researches, perhaps unsurpassed in the history of biology, Hofmeister traced the regular alternation of a sexual and a spore-producing phase in the life-cycle—an alternation between a sexual "gametophyte" and an asexual "sporophyte". Thus the asexual fern-plant produces spores; these develop on the damp earth into minute sexual prothalli, from the fertilised ova of which the familiar "fern-plants" develop. But to follow this clue into the deeply masked alternation that obtains in flowering plants was an achievement of the first rank—so brilliant indeed that it was hardly a surprise when long afterwards there came the demonstration of motile spermatozoa in the pollen-tubes of Cycas and Gingko, which are primitive Flowering Plants.

In 1892, in his *Germ-Plasm* and in earlier papers, August Weismann (1834–1914) made a great advance in the study of heredity. In his exposition of "the continuity of the germ-plasm" he explained, for the first time clearly, how it is that like tends to beget like; he focused the fact of "germinal variations", which was a distinctly post-Darwinian idea; he anticipated the modern theory of the chromosomes as vehicles of the hereditary "factors" or "determinants"; and he subjected to a searching and damaging, if not fatal, criticism the evidence adduced in support of the transmissibility of individually acquired somatic modifications. In regard to all these Weismann had, as usual, his anticipators; but it is due to him to say that he thought out a coherent theory of heredity.

Another great initiator was Louis Pasteur, chemist first and biologist later, who advanced logically from his first study of tartrates not only to a recognition of the manifold activities of bacteria, but to some prevision of the part that yeast and other living "fer-

ments"—through their chemical "enzymes"—play in vital processes. It is impossible to understand either the rapidity or the relative tirelessness of metabolism unless we take account of these ceaseless fermentations.

The year 1904 may serve as date for the demonstration of the rôle of hormones by Bayliss and Starling—a discovery which has deeply changed most aspects of physiology, if not even its main perspectives. Hormones are the potent secretions of ductless or endocrinal glands, such as thyroid, suprarenal, and pituitary, which are distributed throughout the body by the blood, and exert a specific influence—exciting or inhibitory, on the activity of particular organs and tissues. There is no doubt that they exercise a regulatory function in the internal economy of the body, bringing about chemical integration. There is indirect evidence of their presence in the leech and a few other Invertebrates, and more direct evidence of their activity in the Sensitive Plant and some others; but as yet our knowledge of them is practically restricted to Vertebrate animals.

Lamarck (1744–1829) did good zoological work on Invertebrates, he was an anticipator of the Cell-Theory, he was a pioneer evolutionist, but he is most noteworthy for his suggestion that the transmission of individually acquired characters or somatic modifications has been the chief factor in the evolution of organisms. The acquired characters were supposed to be the direct results of changed environmental influence in the case of plants and lower or sedentary animals; but for ordinary animals they were supposed to be the outcome of new needs and activities prompted indirectly by the peculiarities in the environment. The evidence in support of the transmission of somatic modifications remains very unconvincing, though there are some puzzling cases; but perhaps insufficient attention has been paid to Lamarck's emphasis on the share that an insurgent, wilful, struggling organism, full of need or "besoin", may have in its own evolution. Even the most convinced critics of Lamarckism must allow that many an organism plays its hand of hereditary cards for all it is worth.

In 1865 Mendel communicated to the Natural History Society of Brünn what should then have been his epoch-making discoveries in regard to inheritance, but in this little-known publication these unfortunately remained unnoticed till 1900, when similar results, reached independently by Correns, De Vries, and Tschermak, led to a re-discovery of Mendel's far-reaching law and a tragically belated recognition of his buried papers. Mendel was led by his experiments, on garden peas in particular, to the conclusion that an inheritance consists, in part, at least, of the initiatives or factors of clear-cut, crisply defined, "unit-characters", which do not blend or break up, but are typically either continued in the inheritance

as intact entities or not at all. When two parents, belonging to the same species, differ in, let us say, a pair of contrasted or "alternative" characters, the offspring will take after one parent only, as regards that particular character. What is expressed in the development of the hybrids Mendel called a "dominant" character; what remains latent he called "recessive"; but it is not yet known why one character should be dominant and its alternative recessive. If the hybrids pair among themselves, or with others of similar history, then the second filial generation will typically show a

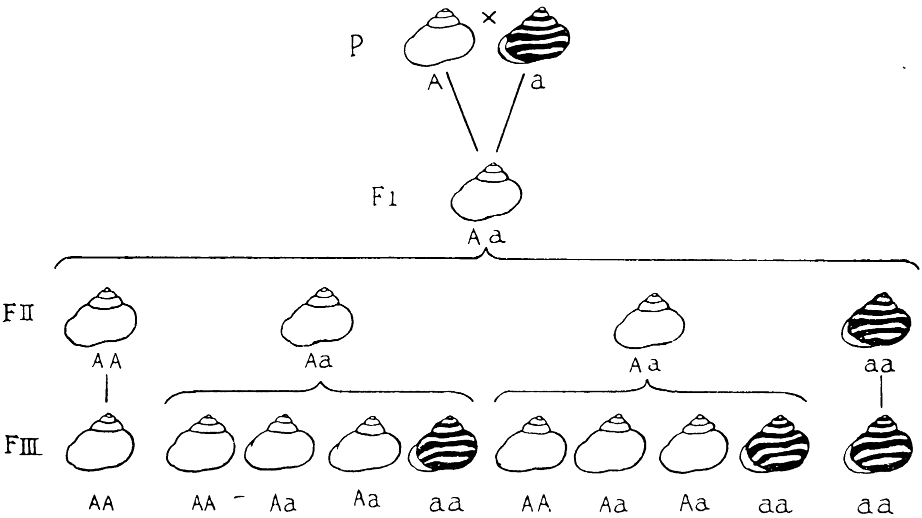

FIG. 202.

Mendelian Inheritance in Wood Snails (*Helix nemoralis*). After Lang. The parents (P) are pure-breeding bandless (A) and banded (*a*) stocks of the Wood Snail. The progeny (FI) are all bandless (A*a*), the bandless character being therefore called dominant. In the next generation (FII), from the inbreeding of FI, there are bandless and banded forms in the ratio 3 : 1. The bandless forms are pure banded (AA) and impure dominants (A*a*) in the ratio 1 : 2. The pure bandless (AA), bred with others of similar history, will yield only bandless. Similarly the pure banded or extracted recessives (*aa*), if bred with others of similar history, will yield only banded forms (*aa*). The impure dominants (A*a*), bred together, will show in their progeny the 1AA + 2A*a* + 1*aa* ratio. See p. 1100.

quarter pure-breeding "dominants", a quarter pure-breeding "recessives", and a half "impure dominants" like the parents. Moreover, Mendel suggested how this comes about by the segregation of the germ-cells of the hybrids into two contingents, one-half carrying the factor or "gene" for the dominant character, and the other half carrying the corresponding initiative for the recessive character. The impulse to further research on these lines since 1900 has been great and fertile.

An influential event was the discovery of the dual nature of lichens by De Bary (1866) and Schwendener (1868), who showed that these familiar encrusting plants consist of an Alga and a Fungus living

together in mutually beneficial partnership or symbiosis. The fungus absorbs water and salts, the alga accomplishes photosynthesis, and lichens will flourish where no other kind of plant can survive. Later came continuators, notably Bornet, Stahl, and Rees, who demonstrated not only strange unions with fresh fullness and clearness, but were able, for instance, to build up a lichen by combining the appropriate alga and fungus. We give prominence to this elucidation of the true inwardness of lichens, because it prepared the biological mind for the discovery of the frequent occurrence of symbiosis. It is widely, though not unanimously, held among botanists that the heather flourishes because it is interpenetrated by a partner fungus; many orchids refuse to grow and their seeds to germinate without their "mycorhiza"; and such fungal symbiosis is also characteristically presented in the roots of many trees. Leguminous plants have their well grown and often nutritive foliage, their exuberant flowering, and their richly protein-containing seeds explained by help of symbiotic bacterial allies in their root-tubercles, which assimilate nitrogen from the atmosphere; and there are not a few other instances of plant partnering plant. All Radiolarians bear small "yellow cells" which turn out to be symbiotic Algæ; and similar partners to these occur in the animal world here and there, as in freshwater sponges and green hydra, in various sea-anemones and corals, and in the green Convoluta, a simple marine planarian worm, of sandy shores in Brittany, lately well re-investigated by Keeble.

The life of many insects, such as beetle-larvæ that feed wholly on dry wood, becomes, to say the least, more intelligible since the fermentative aid of their intestinal yeast-plants and bacteria has been recognised. So plant partners animal. All wood-eating Termites have in their food-canal large numbers of Infusorians, not found anywhere else, without which they cannot utilise their dry-as-dust food. So animal partners animal.

Another biological foundation-stone, which many helped to lay, was the demonstration that all growing and development is associated with the process of cell-division, and that in the ordinary division process the chromatin of the nucleus is divided with meticulously exact equality between the two daughter-cells. Whereas the cell-substance or cytoplasm undergoes what may be called a mass-division, each of the chromatin bodies or chromosomes is split longitudinally up the middle, a half going to each daughter-cell. As this occurs with constancy in the usual process of cell-division throughout the world of life, beginning even in some of the unicellular organisms, it must have a deep significance, part of which is that the chromosomes are the vehicles of many, if not all, of the hereditary and specific characters.

The forces at work in such normal (mitotic or karyokinetic) cell-

division remain obscure, but what takes place has been well observed; and this knowledge has formed, as already said, one of the foundation-stones on which a great biological superstructure has been reared. In 1883 it led van Beneden to another foundation-concept, that in the fertilisation of the egg-cell by the sperm-cell, there is in each of the combining elements the same number of chromosomes, and that the number is half that which is characteristic of the somatic cells of the species. In the maturation both of the egg-cell and the sperm-cell there is a unique kind of nuclear division—called "reducing" or "meiotic"—by which the number of the chromosomes is reduced to a half. Thus when fertilisation is effected, the normal number is restored, half being contributed by either parent. This discovery was followed by the demonstration, first due to Rückert, Zoja, and Haecker, that the paternal and maternal chromosomes and the initiatives they carry are divided with precise accuracy among the daughter-cells into which the fertilised ovum divides. There is cumulative evidence in support of the modern "chromosome theory of inheritance", which maintains that many, if not all, of the hereditary factors or genes are carried in linear order, like beads on a string, in the colloidal chromosomes. Part of the evidence is afforded by the remarkable way in which the behaviour of the chromosomes in maturation and fertilisation harmonises with the facts of Mendelian inheritance.

A momentous event, though its biological import was slow of becoming clear to many, was Thomas Graham's study (1861) of osmosis, and its disclosure of the properties of matter in a colloidal state. The biological relevance of this became luminous when it was realised that living matter is in a colloidal state, with countless ultra-microscopic particles and droplets suspended or dispersed in a more or less liquid medium, and affording in proportion to the total mass an enormous surface on which a multitude of chemical and physical actions may take place.

It was an important step, with far-reaching consequences, when, about 1899, W. B. Hardy showed that active protoplasm has no visible structure under the highest power of the microscope, but presents to the ultra-microscope the characteristics of a colloidal system. Careful observers had described the reticular, fibrillar, or other intimate structure of dead and fixed protoplasm, but the complex microscopically visible framework was shown by Hardy and others to be an artefact, a result brought about by the methods of fixation. Active protoplasm is a fluid system, with not less than 70 per cent. of water, and contains innumerable mobile particles and suspended droplets. From this "sol" state the active protoplasm may sink temporarily or fatally into a "gel" state, like set jelly or boiled white of egg.

There are often microscopically visible particles in a cell or in a

drop of protoplasm, which sometimes quiver in a "Brownian movement", due to their being jostled by the wandering molecules; but these are less important than the ultra-microscopic particles, which cannot be directly seen owing to their minuteness. Though invisible, they are demonstrable by means of the ultra-microscope, which reveals their diffraction discs or haloes of reflected light. The multitudinous surfaces of these ultra-microscopic particles and droplets afford opportunity for chemical and physical changes to occur, as the coast-lines of an archipelago of islands do for trading and fishing, and this is what makes the colloidal state of protoplasm so fundamentally important. It may be added that while Hardy and others showed that the microscopic reticulum does not correspond to the natural condition of the cell, there must be *some* arrangements, probably of a film nature, which separate one area of a cell from another so that different chemical processes go on simultaneously.

We must include among the great events in the history of Biology the introduction of statistical methods, for it meant the discovery of a new organon of research which, in the skilful hands of Galton and Pearson, Weldon and Pearl, has made important contributions to the study of variation, heredity, selection, and population.

One of the seed-ideas in Biology is the inter-relatedness of organisms, and it may be particularly associated with Darwin. It was no doubt in Gilbert White's mind when he wrote the famous letter on earthworms, and in Sprengel's when he traced the colour signs and wayposts, landing-stages and hand-rails that attract and guide pollinating insects to the nectaries; and there were not a few other precursors and anticipators. Yet far beyond all these Darwin stands pre-eminent in his vision of the correlation of organisms into the world's wide, ever-weaving web of life, and he more and more discerned this as the essential drama of biology. As John Locke said, everything is a retainer to some other part of Nature. Thus earthworms plough the fields and plant trees; the bee and the flower become fitted together more intimately than hand and glove. The missel-thrush sows the mistletoe; the minnow nurses the freshwater mussel; the pied-wagtail helps the sheep-farmer; and the squirrel has its share in making the harvest a success. According to some historians, the glory of Greece was partly dimmed by the intrusion of malaria. As this disease is disseminated by mosquitoes, and as the mosquito larvæ are very effectively kept in check by minnows and other small fishes, we see a new meaning in the exclamation, "Ye Gods and little fishes!" Now it is not merely that these and a thousand other linkages are interesting facts in ecology; they illustrate the evolution of a manifold Drama of Animate Nature which has been in progress throughout geologic ages. Apart from para-

sitism, the many external linkages that have been established operate against retrogression and often towards further advances. Thus the Yucca moth and the Yucca flower are so adjusted together that there is no room for freakish variations that would imperil their successful inter-association. Furthermore, we must think of Natural Selection as often sifting in relation to a very fine-meshed sieve—the complex system of Animate Nature.

With the publication of Darwin's *Origin of Species* (1859) the evolution-idea of Animate Nature, suggested by many anticipators, began to become widely current intellectual coin; the more since then it was shown that the factors in the process, such as variation, heredity, and selection, were amenable to scientific treatment. This was the disclosure of a new world, for the realm of organisms was henceforth to be envisaged as the outcome of a long evolution, which, moreover, was still being continued. As Renan put it, the contemplation of a state of Being was replaced by an inquiry into a process of Becoming. And Hegel had discerned the like in his abstractional way.

We cannot conclude this merely illustrative survey without suggesting that another great event in biology has been the gradual recognition of the open secret that "mind" is a factor in the life of organisms, and has been a factor in their evolution. The extreme behaviourists deny that mind functions as an appreciable *vera causa*, but there is strong analogical evidence that the animal often acts on the strength of some psychical activity, such as is implied in a memory or a mental image, a desire or a surge of emotion. We get hints of this in the animal's search for suitable environments, in some of its subtler life-saving devices, in persistent endeavour towards a distant goal, in instances among higher animals of perceptual purpose, in the training of the young, in the conventions of animal societies, and in occasional cases of intelligent and sympathetic co-operation with man. Perhaps one may say that Lamarck and Darwin, so different in detailed theory, were akin in their rejection of an apsychic biology.

APPENDIX II

NATURALISTS AT WORK

THOUGH the world needs far more biology than it yet knows, progress towards this has always been going on outside our special departments in universities, and other technical studies and publications. Thus zoological gardens arose from travellers' home-bringings, and public as well as princely interest in them; and so even botanic gardens, of which the first in Europe arose from the high appreciation of the city of Venice, then richest in foreign commerce, but poorest of all in land, which yet gave its best unbuilt area as home not only for its doctors' herbs, but for the useful, the beautiful or strange plants gathered in seed or shoot by its far-travelled citizens. Next (1593) the Montpellier Garden, whence ours.

Whoever goes out for a woodland or seashore walk—when not too preoccupied to enjoy it—is already something of a naturalist; and yet more his child-companion, who may run about well-nigh as actively as their dog, and not merely after the rabbits, but gathering shells or pebbles, picking up here a feather and there a flower. Indeed, what are the most productive of naturalists, and even of biological thinkers, but such children, who, instead of losing these interests, or having them repressed, as more commonly, have continued and developed them in larger growth? Thus the truant Darwin—albeit later the greatest of naturalists and of nature-thinkers in one—is typical, and even as normal type: for his vagaries in youth were necessary for such naturalist's life, voyaging and thought, as education yet allows. Even his supernormal "genius" admits of intelligible interpretation. For books like Gilbert White's *Natural History of Selborne*, and biographies of naturalists less favoured by good fortune, like Thomas Edwards, Charles Mackintosh, and more, illuminate Darwin's: indeed, the latter prove how often Nature is mothering such village Darwins, mute inglorious though they may commonly remain. The life of Sir William Flower—a late eminent Director of the Hunterian treasure and tradition of the London College of Surgeons, and then of the British (Natural History) Museum—links together all extremes between villager and Darwin, between pretty feathers and world-museums, by his own story of the origins of his career as greatest of curators and collectors, telling how this all began for him as a small schoolboy gloating over a battered but still bright stuffed bird in a shop-window corner, and attaining the state of ecstasy

when (for threepence) he obtained it, and had thus the beginning of his first (attic-shelf) Museum.

Much as the inroads of the industrial age aroused painters to appreciate and record nature and cities in their undestroyed beauty, and thus soon to bring their art to foremost rank, so also it has given a like impulse to our scientific appreciations and records, alike for nature-studies and for humanities: thus largely our modern biology, indeed sociology as well.

In our age of speech and press, the exponents and advocates of biology must needs lecture and write books; yet science, like society, needs organisations too, and of all kinds, from public to specialistic—in time directive, as from army-recruiting to staff. Hence, then, the values, both individual and social, of naturalist societies, small to great, local to metropolitan.

Their fuller development and linking are next needed, as in the civic and regional society with its museum; and these for a good many years have been in progress. Among the foremost of these—on Flower's widest authority, and not merely our own experience—is the Perthshire Society of Natural Science, of which the active regional exploration and initiative—well headed by men like Buchanan White for botanist, James Geikie, then on Geological Survey, and first-rate sportsmen-zoologists too, but also supported by keen naturalists of all social classes and levels of education—produced the first of our British regional and type museums. There are many other good examples of active societies; but let us here next specially signal their larger regional unions, e.g. the now well-advanced Union of South-Eastern Naturalists' Societies, which meets by turns at Woolwich, Croydon, etc., and publishes excellent work. Thus too the annual conference of Naturalists' Societies at the British Association is well worth attending, as also the annual gatherings of the new profession of Museum Curators; and latest, yet most comprehensive of all, the vacation outings of the Regional Associations. For in all these ways we have the needed regional network of nature-studies spreading over the land, and preparing to net in the embryonic Darwins, at any rate the young Flowers, and fish for active-minded men and women too.

All these movements are essentially of our elder generation, and thus might pass with it; were it not for the young hopefuls of the world-wide Boy Scout movement, and of its smaller, yet very promising congeners or offshoots, like Woodcraft Chivalry and Kibbo Kift. Hence now to hand on the tradition of our passing generation to the eagerness and initiative of the rising one is immediate and urgent for both. Indeed, the problem confronting the active spirits of these movements, of how the education of the bulk of their adolescents leaving them is not to lapse, is now actually being put to us all; hence museums, societies, and university

departments alike, have here before them—quite literally and fully—"the chance of their lives". In this way, too, we shall soon be seeing more biological laboratories in the schools, beside their present chemical, mechanical, and sometimes even physical ones. Thus a needed and great development of the educational ladder; moreover, in the Universities the value and significance of the biological sciences, as the essential link, too long missing, between the sciences and the humanities, will become far more clear than hitherto to their respectively too exclusive exponents. And, of course, also to the public. The age of biology, and of sociology also, will then have adequately come. Till then we are but in the day of small things.

BIOLOGISTS AND BIOLOGY.—With nature-studies actively in progress, and regional life-surveys extending with opportunities of travel, naturalists go on happily, finding fresh things and seeing them in new lights, even in old age; thus verifying Meredith's good saying: "Observation is the most enduring of the pleasures of life." Grey and wrinkle-eyed as they become, they are still the same boy-naturalists as ever, the same student-ramblers, questing from moor to shore. Earlier interests continue and develop: one goes on watching his birds, another his flowers. Breadth of nature-interests need not be lost; the zoologist is all the better for being a garden-lover, and the gardener-botanist may find his best opportunities in planning Zoos. Thus neither loses sight of the plant or the animal world; each is kept awake to biology in its twofold comprehensiveness. For though specialised interests must needs diverge as they develop, these are now less prosecuted as the too isolated specialisms into which the sciences too readily fall to pieces, as well as asunder: they are also conspecialisms, since more and more realised amid the interactions of Nature and in the interchange of minds.

Here two little anecdotes of Darwin may make this normal naturalist's progress more vivid. One day, many years ago, the writer of this section—then an assistant to Burdon Sanderson and Schafer at University College—was amusing a spare hour by searching a pond-sample with his microscope, and had drawn a comparative blank, with only two or three common green Euglenas swimming amid a few motile bacilli. He was about to put this slide away for a fresh dip, when he was gently pushed aside. A big beard came over his shoulder—here was Darwin! who had come in unnoticed. He said nothing, but looked closely into this—to me—barren microscope-field: then suddenly broke out, positively shouting for joy: "I say! They're moving, they're *moving*! Sanderson! Sanderson! Come and see; they've MOVING! Look at that!"

Was not here a vivid and memorable lesson in biology—this literally Pan-ic intoxication of ecstasy, in our oldest of veterans, greatest of masters, before this simplest spectacle of Life!

The other story, from a year or so later, was told me by a close friend, George Murray, then keeper of Cryptogams in the Natural History Museum, as he returned from a week-end at Down, to which Darwin had invited a few other younger science-men from the Museum and from Cambridge. Murray told how Darwin had spent the previous evening questioning each, and drawing him out on his subject; for no man was more open and eager to learn. Then, leaning back in his chair, he said: "I am always feeling my ignorance, but never have I had it more strongly brought home to me than to-night. You have surprised me!—and again and again! What you" (pointing in turn to each) "know about cryptogams, and you tell me about phanerogams, and you about bacteriology, and you about embryology, and you about fishes, and so on, is most interesting! It's something astonishing! You do indeed make me feel my ignorance, and what I have missed!" Pause: then jumping up from his chair, and with thump on table: "But—damn you!—there's not a Naturalist in the whole lot of you!"

Was not that startling—and wellnigh Roman-father-like succession, first of laurelling, but then condemnation,—a great lesson, fit to last through each life? Due appreciation of all specialisms, yet right protest against their too great isolation, emphasis on biology as conspecialism, visioning Nature and Life.

Thus through life (as now, and emphatically, in this joint endeavour before the reader), we are not content to continue simply as field-naturalists, whether in the woods or by the sea. We go into more deeply observant scrutinies, one after another, but also seek more understanding of them in relation to the whole; and we may thus pass on Huxley's saying, "Any collector can show me species I have not seen before, but the man I want is he who can tell me something more about the commonest ones, dog or cat, horse and cow, and so help me to understand them better."

Hence, after Huxley's own naturalist's voyage, when he settled to teaching, the great advance he made was that of the Biological Laboratory, with its practical Type-system, a broad course on chosen plant and animal types, from Amœba to Hydra, bacterium to alga, fern and flowering plant, and from worm to lobster, to fish and frog, to bird and mammal. Here was a more varied and rapid, more interesting and more instructive, because more comprehensive, introduction to biology, in its many aspects and problems, than those of the traditional and separate academic courses, as of botany and zoology in the first term of medicine, and anatomy and physiology later. An excellent preparation for all these; as his own further course showed, with its careful dissections and comparisons, so illuminative of comparative anatomy, and of its applications to the advance of classifications, in increasing approach to evolutionary presentment. One recalls too his vivid teaching of elementary

physiology—whence his introductory manual, classic for fifty years, and needing little re-editing even to-day. His lectures were thus unforgettable, since often equal to his best-known *Protoplasm, the Physical Basis of Life.* From precise observation of the well-chosen dissections, skeletons, and fossils on the lecture-table, emphasised by swift, clear sketches on the board behind, he roused to interest and trained to clearness his hearers' minds, even to enjoyment of his rigorous reasoning, step by step, comparison by comparison, until the full design of his discourse stood out in its clearness of intellectual beauty before us, whether it were the build of crustaceans or of crocodiles and their outline pedigrees, or that of the horse. Thus what separate teachers had too long made but dull anatomy here and tedious osteology there, and so on for isolated subjects, were patiently wrought together into a great presentment of organic form in change; forms thus no longer static, but dynamic, physiological, evolutionary. In a word, here was our first vision of Proteus in Evolution. Thus and thenceforward Goethe's term, "Morphology", became for us no longer harsh and crabbed, but true music of the poet's lute; and we hear in it still the tersest and most enduring expression and result of his long life of scientific observation and meditation in philosophico-poetic spirit, and thus with evolutionary insight beyond his times.

In summary, then, for the essential ideas, the master-keys, indeed, of comparative anatomy and taxonomy, of palæontology and embryology, in short the four main fields of morphology, Huxley's teaching was the best of introductions, even beyond his books. And so for physiology; his explanation of the dynamic activity of living forms, as in locomotion, in respiration and circulation, in nutrition, and so on, was always masterly in its simplicity and clearness. His presentments of life-processes were also, as far as might then be, fundamentally physical and chemical; a view by him most clearly stated, though great advances have now made it widely familiar.

Beyond the four morphological sub-sciences aforesaid, Huxley thus introduced not only his too few students, but largely the wide public, to the conceptions of the physiological group—those not only of physiology in its usual technical and restricted sense, but very notably to those of evolution, of ontogeny and phylogeny. For Haeckel was then teaching us to correlate the development of the individual organism with that of its species and race, its vertebrate or invertebrate stock; and these in boldly attempted correlation. How this? Through "recapitulation", that of the race-history in the individual's development; though this as more or less abbreviated and modified in adaptation to environment, and to internal needs, and controlled by natural selection, continuously at work accordingly. No wonder then that Huxley became one of the first,

and certainly the foremost, of the paladins of Darwin in those great years of battle which followed the publication of *The Origin of Species* in 1859.

Yet no man reaches completeness; so the one lack of his teaching lay in its too scanty reference and impulse to living "natural history"; though he would at times mention how Buffon had taught it, or how Darwin had so especially advanced it, with his studies of the inter-relation of flowers and insects, the strange sex-ways of cirripedes, the soil-making of worms, and other bright disclosures of strange scenes in the drama of Life. All this is "Ecology", as Haeckel called it, in his admirably reasoned *Generelle Morphologie* —his first and greatest work, of which the long-continued neglect by his brother-biologists, even though evolutionists, turned him to his later and more popular endeavours. Indeed, this book (now valued and hard to obtain) followed surprisingly soon upon the *Origin of Species*, and developed its main theses with vigour, fullness, and intensity, surpassing even Huxley's sturdy championship, but also often went beyond those of Herbert Spencer's long famous (and still not to be neglected) *Principles of Biology*.

Huxley was, however, too great not to know his own limitation as well as his powers; he even summed these together, as he indeed said to one of us: "You see, I should have been an engineer!" Yet, to do him justice, though he never took us for an excursion, nor even sent us to the Zoo or Kew, he did the writer the inestimable kindness of introducing him to Roscoff, that most admirable of Marine Zoological Stations, founded by his friend Lacaze-Duthiers, on the northern coast of Brittany, where the Channel fauna is at its richest and best, and where students were trained, and investigators encouraged, to search the shore and dredge the bottoms for their material, along with Lacaze's naturalist-fishermen, instead of having all bought for them or brought to them, as too easily elsewhere.

Lacaze, though the skilled and subtle anatomist to Huxley's admiration, had not Huxley's comparative powers. It was as field-naturalist that he surpassed him; with his lecture-table magnificently covered with aquaria, teeming with all the living wonders of the sea by turns; these being sent up weekly not only from Roscoff, but also from his Mediterranean station at Banyuls, on the coast of the Eastern Pyrenees. And when Christmas and Easter vacations came, his best students were mobilised and packed off to Banyuls, as for the long summer vacation to Roscoff; for even the less willing found it hard not to follow so splendidly life-intoxicated a leader; in this respect the very peer of Darwin himself.

Enough, then, to justify the need of continual return to nature-study, linked with active research, both with reflective interpretation. All three moods and modes of inquiry have been well-marked

in the career of Delage, Lacaze's eminent successor; and indeed of not a few others of the widely international fraternity of "Roscovites", one still growing. Biology has room and need for all types of mind, from simplest observer's to deepest philosopher's: but neither prospers best alone; for then one sinks to mere collecting, and the other risks coming to what Huxley called "Mr. Spencer's idea of a tragedy—a beautiful hypothesis murdered by a horrid little fact!" Science is first of all inductive: hence it is some fresh first-hand observation which best sets a bright mind working, and to search more deeply: thus Mendel's was stirred by his garden peas, tall and short, green and yellow; Weismann's theories, of germ-plasm and more, started from observation of hydroid's and Daphnid's eggs; Metschnikoff's invaluable interpretation of inflammations, even his well-known contribution of Bulgarian milk to dispel digestive disorder and promote longevity accordingly, alike came from his first observations of Hydra's (simplest possible) alimentary canal; and, as he says himself, from watching what happened when minute crustaceans answered back to an irritant intrusion. Pasteur's great opus began with puzzling over left-handed crystals, and even more with sour milk, bad wine, sick stock, and other rustic matters, seeming of no scientific importance before; while his no less immortal disciple, Lister, may be simply represented as a modern variant of "the shepherd with his tar-box by his side". Thus the Antæus of the spirit must ever renew his strength by coming into touch with Mother Earth; and in short, every Newton must needs have his apple (whether that particular story be apocryphal or no).

DARWIN.—In these two generations since *The Origin of Species*, we have been searching into some of the internal factors of evolution—which it is but fair to say Darwin was himself open to, and even actively feeling and searching his way towards. Yet too few who have been or are on these new quests (as indeed throughout life ourselves) can avoid being fascinated, or at least biased, by the new and interesting conceptions these have been yielding; and thus specialising on these so strictly as more or less to lose that comprehensive view of the whole life-problem with its many life-aspects and situations which it was Darwin's ambition to attain, and his example to strive towards; for in this largest survey of life and its continuance and progress, he saw even his own doctrine of natural selection as but part, and often candidly said so. It was, of course, but natural also—and, as we shall see later, especially in Darwin's day and generation—to specialise too extremely on this one doctrine, even to its "all-sufficiency"; and thus to provoke reactions against that ultra-Darwinism which he did not himself affirm; but the like of which has so commonly arisen among the devoted disciples of each new thinker, who have ever so readily

tended to become *plus royaliste que le roi*. But it is also for each of us who attach more value to those further and deeper-lying factors of evolution which Darwin himself descried, though he could not clearly foresee, to avoid spreading our sails too widely to each new wind of doctrine, above all if it be our own favourite one.

With this preamble, we are ready to consider the significance of Darwin's work more clearly still. The study of variation has now gone beyond his own endeavours—as indeed also to beyond Neo-Darwinians, Eimerians, De Vriesians, or even Mendelians, and all the rest of us, since each still too separately insistent. For it stands ever open for other factors still; and, above all, looking towards co-ordination of all the many variations-factors we can find or hope for. Yet we must not lower the value of each and even all of these, by failing to recognise that all variations whatever are, and have to be, tested by their survival value, in that judgment-day for each specific function- and form-variation, and its individuals and species accordingly, which is ever going on. Hence we all have to return to Darwin's vivid example, and utilise and apply it yet farther, before we can fully understand the mingled fortunes of each type and form of life in its urge and struggle between failure and success. Here Darwin's own struggle is worth recalling.

See him setting out, as active youth often has to do, with healthy escape from school and university conventions into ever-widening circles of eager scouting through Nature, and from truant's foot-range to wide and open-eyed world exploration. See him thence returning to ever more variedly observant and reflective quests, and all towards building up the general concept of evolution, and this from the geologic past up to the human present; hence continuing Lyell's evolutionary masterwork for geology on one hand, and then marshalling, with magistral summing-up, all the main lines of biologic knowledge into the evidences of organic evolution, and at length fully realising his own great contribution of natural selection to its interpretation. This was potently aided—as for Wallace as well as himself—by help of the problem of human population then so sharply posed by Malthus. Yet beyond this and other help from the social and utilitarian economic thought of his time, and supplementing this by rural participation in the practical advances of agricultural and kindred labours of domestication and breeding, he also shared in his own way the meditations of historians, and yet more utilised the discoveries of pre-history towards the understanding of man's ascent. He even humanised this more fully by his still fundamental evolutionary contribution to human and comparative psychology in *The Expression of the Emotions*. Again see him unravelling the ways of life, the simple mothering of mammals, the courtship and song and nesting of birds, with their

anticipation of our human lyrics of love and family and home; so thence his wisdom culminates in a theory which for each species hopefully interprets life's tragedies of individual struggles and imperfections overpowered by hard fates, yet also insists above all on the far more than individual significance of survival, to its happy climax, that of race-continuing and family-founding, open to further achievement. Hence, despite his usually quiet and homely style of exposition, his work had in it more gifts from the Muses than he realised; so that his masterpiece could not but terminate with a synthetic passage of true and widely convincing eloquence, a veritable climax for his own evolution, fitly part of that of Nature.

BIOLOGICAL CONCEPTIONS SOCIALLY INFLUENCED.—Now though in our summer school (explained pp. 1384–9) biological surveys and interpretations daily accompanied the social, it was also evident that for most auditors, the social view, as the one humanly familiar, helped greatly to throw light on the biological ones; while even the lecturers, albeit more familiar with Nature, could not but sometimes feel of the same way of thinking too. The popular belief as to naturalists, and which they naturally share, is that each leaves his city and his social life in it, and goes out open-mindedly into Nature, thus perfectly set free to make such observations and interpretations as that environment can yield, and thence bring them back to his fellow-citizens; and these too are assumed as no less open-mindedly ready to receive, and discuss and adopt them as new truths. All so far true, good, and well. But "the eye only sees what it brings the means of seeing"—so, too, the naturalist, what he was prepared by his previous social as well as naturalistic life to see. Take, for instance, the Darwinian doctrine of natural selection. Among the greatest naturalists, we cannot think of better observers than Darwin and Wallace, nor of finer and fuller nature-experience than was theirs; nor yet can we imagine more open, truthful, and honest reflective minds as well; so when such men bring back their great collections of new wonders of life, new observations on them also, we accept them as true novelties. And the like for their fresh interpretations as well, their separately reached and confirmed doctrine of natural selection above all. Yet in their very rebound from social constraints, their conventional education especially, they were fruitfully striving towards the enrichment of these, and thus true educational and social pioneers, since whom nature-studies have been more seriously considered. Their theory seemed to all, as to themselves, also derived directly from Nature. Yet when we once asked Wallace, "How did you come to the theory of natural selection?" he replied, "Oh, just like Darwin, from reading Malthus!" So it was thanks to Malthus, as political economist, raising the question of human population, and.

to his public, as far as possible from field-naturalists, that each of these naturalists was independently stirred to supply the element of interpretation Malthus had missed. For where he saw only the survival of the survivors, from elimination he thought of as indiscriminate (unless providential), they saw that even in poverty, hunger, and disease, and other checks to population, there was still large scope for the escape of those best adapted to their environment; in short, the survival of the fitter and the fittest—"natural selection" accordingly. We are thus ready to understand that eminent American historian of economic theories, when he describes Darwin as "the last of the great British economists".

Again, in further conversations with Wallace, and in the rich and beautiful garden he had made, he would pull a flower among those he loved and lucidly descant upon each of its details of form, as of adaptive origin, even to expressing his convinced faith that the curious and characteristic wrinklings of the corolla of the Snapdragon (Antirrhinum) had had the like origin and survival value, even if he could not yet demonstrate this. Here then, full and clear, was his general view of the flower, or other organism, as an amazingly complex resultant and co-adjustment of gradually accumulated advantageous and thus successful variations. He did not indeed use the analogy of the complex machine, built up to its modern elaboration, as resulting from the successive incorporation of innumerable minor patents into the simple original one; nor at that time did one think of this analogy either. Yet our later reflection still remains clear of him, of Darwin, and of ourselves as so far Darwinians alike—that here in the industrial age, with its many inventions, was at least a subconscious source of such suggestion. Recall that Darwin expressed indebtedness to having had to read, for Cambridge University entrance, Paley's *Evidences of Christianity*, with its famous illustration of the watch found on the heath by some one ignorant of such a strange machine, yet thence reasoning to its design by its watchmaker. It is, of course, of the very nature of science, even before any concept of evolution, to replace such theological anthropomorphism in terms of orderly causation. Our modern knowledge of watches and other complex mechanisms is of all having progressed, by incorporation of successive inventions, with fuller and finer adaptations to use; so with consequent survival of each improved type of watch over its predecessors, yet its supersedure in turn by further improved successors. We are thus already thinking in terms of the general process of evolution. Thence to project this conception of such progress—so akin to cumulative patenting—upon the variations more or less observable in every kind of organism, and to see that those favourable to better internal working, or to external adaptation, should be of advantage to its more efficient functioning, and thus to its survival and continuance,

is a rational conception. And conversely, that unfavourable variations are thereby disadvantaged, and so tend to disappear before their betters. Hence, after all, the wonder—as with so many other advances (before and after Columbus' egg!)—is that Darwin and Wallace had not yet more anticipators in this idea, of survival of the fitter and establishment of their types accordingly, than their two or three predecessors (as notably Patrick Matthew, for timber; or for human races, Dr. Wells), whom Darwin loyally acknowledged, but who failed to realise the wider application of their hypothesis, and to work it out further into general biological theory. In such ways then, do we not see how this theory was as thoroughly congruent with the development of our age of mechanical advance, as was Paley's watch theory—for theologians, at least—with its beginnings? In fact, even in these beginnings, its very foremost figure, James Watt, had gone beyond Paley; for when asked, "Why do you not advertise your new steam-engines?" he replied: "It's not necessary, our works are as busy as they can be; and besides, there soon won't be any of the older kinds of steam-engine left in the world!" There is a clear anticipation of natural selection, though not applied to organisms. It also helps to illustrate how, since in Darwin's generation the British public was then easily leading the world in mechanical invention and progress, it had a good many minds ready for this kindred biological doctrine. But it may be said—the doctrine found wide acceptance in Germany, not yet so industrialised. True, but aided by a different progress, that of the impressive extension of Prussian victories in the decade after *The Origin of Species*, with conquests accordingly, as of Schleswig-Holstein in 1864, over Austria, and of much of South and West Germany in 1866, and of Alsace-Lorraine in 1870–71, with full development of Empire accordingly; so that in these expansions (as indeed, though less dramatically, with British imperial extensions), there were social examples of the associated biologic conception, that the forms of life successful in surviving their struggle for existence naturally extend their area of geographical distribution as well. In France, however, the Darwinian doctrine of evolution through natural selection made much slower progress; so with her relative inferiority in manufactures to Britain, and in war to Germany, it seemed to these countries fresh evidence of her backwardness, that even such evolutionists as there were should still remain more in line with Buffon or with Lamarck; and thereafter—though not, of course, without some complete acceptances of Darwin—be more inclined to neo-Lamarckian doctrines than to Weismann's or other neo-Darwinian teaching, and thus be more ready for Bergson's *Evolution Créatrice*, with its substantial revival of Lamarck's essential doctrine. His conception—too readily misunderstood by German and English-speaking biologists as mere "inheritance of acquired

characters", so scant of evidence, and dubious at best—was an essentially psychological interpretation of organic need and urge, *besoin et désir*, and hence readily revived, as *élan vital*, or again as *libido, hormé*, and the like, all viewed as of origins more or less subconscious and organic, amending the too anthropomorphic and even economic associations of Lamarck's phrasing, especially when translated as "need and desire", of which the customary use is so conscious in ourselves.

But next, how came Lamarck to this doctrine? From his fruitful study of the Invertebrates, we are told, and as he largely thought himself. But in that extraordinarily speculative mind, with its exceptionally wide range—as from the foundations of chemistry to the initiative of modern weather-prediction—there may well have been other scientific factors as well. Yet beyond these again—just as Darwin profited consciously by Malthus as economist, as well as less consciously from the British industrial revolution with its mechanical progress—we cannot but see in Lamarck one of the most representative minds aroused by the intellectual life which preceded the French social and political revolution, and accompanied and followed it also. Recall the doctrines of Rousseau (himself at first an effective writer in botany), as leading prophet of his age, with his rights of man, his sanguine enthusiasm, faith, and hope in education, in progress and perfectibility, through liberty, equality, and fraternity. All this seemed in Lamarck's youth a veritable evangel; and even in disillusioned or coldest retrospect, who can refuse such doctrines of progress the credit of forerunning—in however naïvely emotionalised and abstract terms, so with little of science—our general conception of Evolution? Like other radical aristocrats, the Chevalier de Lamarck willingly dropped his title and heraldic status for plain citizenship; hence in every way he was prepared courageously to think out his theory of organic evolution, and appropriately in terms thoroughly congruent with "the career open to talents", and of "the soldier carrying his marshal's baton in his knapsack"—phrases which Napoleon, despite all elements of reaction in his career, so convincingly expressed and even largely realised in his day, when Lamarck's thought was ripening. In short, then, his evolution theory—whether we share or reject it here matters not—is also a characteristic product of his social environment and times, and outlook in them, as all thought more or less must be.

Had we space to outline the history of biology, we might cite many other instances of social influences on its thought, however unconscious. Thus what of Bonnet's *Echelle des êtres*, his simple and non-evolutionary classification of animal life, which assumed an orderly and practically linear series of forms from simplest to highest, from animalcule to mammal; and which one finds practically

surviving in conversation even to these days? This doctrine is as far from the facts of nature as may be: so how could it occur to so intelligent and otherwise productive a man of science? One can find no explanation but the social one; that of a Genevan Swiss, i.e. of mingled plebeian and patrician democratic environment almost like old Rome itself, coming to Paris and its Court, while this was still strictly hierarchised in order of precedence, from page-in-waiting up to dukes, princes, and king; and the like in army too. And since already accustomed also to his own church hierarchy, from chorister and bell-boy behind priest at mass, up to bishop and archbishop, cardinal and Pope, how easy for him to make his fable of a like ascending ladder of organic beings up to Man—indeed, how difficult to escape approving such hypothesis in such social conditions; and with survival of it in what remains of their atmosphere. And when we pass to Cuvier, historically the central master of comparative anatomy and palæontology, we cannot but liken his animal classification, of five main types of animal life, and his active resistance to the evolutionary teaching of Geoffroy St. Hilaire and others of his time—even Goethe among them—to the five social orders of his day, which, as statesman and peer of France, he no less stoutly defended against revolutionary spirit and endeavour. Even in our greatest master Linnæus—from whose classic *Systema Naturæ* all naturalists are agreed to date our modern era—the like social influence is not far to seek. For in his day Sweden was still the most conspicuous and glorious of the military Powers of Europe; and he had even his own turn of army service, and as a quartermaster, an officer whose duties involve very varied attention to the whole life of the regiment he has to provide for. In such a militarised country and military atmosphere, what more characteristic than its clearly defined grouping of individuals into squad (or variety), these into company (or species), these again into regiment (or genus), and so on; as his classification so plainly does? Given then a super-mind, habituated to this military order of men, things, and thoughts, yet happily of overpowering rural interests and orderly gardening ability as well—even to delight of Dutch taste, then leading—what could be a more natural, rational, and practical idea than that of applying the clearest and most fully developed of all forms of social organisation so far, that of his country's super-armies, to bring their order and method, their marshalling and comprehensive review, into his ever recruited collection and extending survey of the varied and multitudinous forms of nature? With such a mind, such effective ambition of world-conquest, albeit in a new way, what a superlative military organiser was lost to Sweden, and spared to Europe! Note, however, that Linné's Artificial System for botany, with all its high authority, had to give place to the Natural System; and this latter was estab-

lished by the planting of its first botanic garden at Montpellier, more than two generations later, by a Genevan Swiss, A. P. de Candolle; and also in the British Museum by Robert Brown—Humboldt's *facile princeps botanicorum*—the Scots traveller who best explored the flora of Botany Bay, etc., and who had early broken away from the extremest logical strictness of hierarchic conservatism on record—that of his father's cottage parsonage and episcopal palace in one.

For final example, return to the evolution theory and its important contributions. Take Kropotkin and his *Mutual Aid*, a sound and valuable application of the social factors observable in animal life and evolution; and this clearly suggested by his own life and experience of the co-operative and kindly ways he knew in the old Russian village-communities, and the comradeship of labouring guildsmen in the towns. Unlike previous naturalists, he was quite conscious of this social indebtedness. And as we have come to realise this suggestiveness of the more evolved human life towards the understanding of the ways of simplest beings, we also have learned something, for our fundamental interests of biology and evolution, from such experience in education and citizenship as we have found opportunity for; and so have all confidence in passing on the recommendation of such interesting and widening experiences to younger nature-questioners in their turn. And this the more since without some such experience of social life, and on its constructive lines of evolution, they are only too liable to influence from those perversions of Darwinism so long and still current in the competitive, mechanistic, and militant world of "progress"—on lines of evolution we cannot but think other than those of nature or society towards their best.

If the reader doubt the above endeavours to correlate scientific advances and discoveries (and limitations or errors also) with the antecedent life-experience of their initiators, it may be replied (1) that these attempts are in keeping with the rationally interpretative biographic method now increasingly familiar and acceptable, even in other and more difficult cases and fields. Also (2) from the outlook of life at its widest—including psychological and social aspects and factors—all such attempts to correlate new and significant thought-adaptations (or mis-adaptations) with their eco-psychologic conditions, are legitimate parts of developmental and evolutionary inquiry; and thus complemental to the more familiar study of heredity, of course also needing to be pursued as far as may be.

APPENDIX III

HOW A BIOLOGICAL OUTLOOK ON LIFE AND ITS PROBLEMS CAN BE DEVELOPED BY EDUCATION

WITH change of perspective let us now turn to another practical question: How the biological outlook on human life may be developed in the course of education.

By the biological outlook on human life is meant thinking of ourselves as evolved and evolving organisms, struggling and co-operating, multiplying and developing in an evolved and evolving environment. Evolving may be, of course, in a minus as well as in a plus direction, or even between the two.

The biological outlook implies a full recognition of the fact that the social co-ordinates: FOLK, WORK, PLACE, and also in reverse order, PLACE, WORK, FOLK, correspond to the biological co-ordinates: ORGANISMS, FUNCTIONINGS, ENVIRONMENTS: or, again, ENVIRONMENTS, FUNCTIONINGS, ORGANISMS.

It is plain enough that the biological outlook cannot be rapidly acquired, for it is the outcome not of direct instruction, but of a sympathetic attitude to life and an intellectual discipline in its ways. It implies a mental habit, the result of successful observation, experience and reflection, which leave the inquirer impressed with the value of looking at human life in the light of biological principles. Not that this discloses all the facts, for it requires to be complemented by Psychology, Sociology, Ethics, and even Religion.

Except in the mentally resolute, a vivid biological outlook is rarely gained apart from some tradition. In most cases the student comes to look at life biologically, because his teachers, parents, and associates look at life in that way.

The meaning of the biological outlook may be clearer if we contrast it with the non-biological way of looking at human life—not that any one can be entirely non-biological. The biological outlook implies a recognition of man as a living organism, the highest of the mammals, with all the vital processes of other animals, with harmonious functioning that spells health, with liabilities to disharmony that lead to disease, and with a very important regulative system whose hormones are essential to the welfare of body and mind. The psychical aspect is as supreme as the protoplasmic is fundamental, but while the body may be thrilled by the mind, it is not less true that the mind is thirled to the body. The unity of the organism is a basal biological truth.

Secondly, the human organism lives in an environment which

must fulfil certain minimal requirements of food, fresh air, space, beauty, change, and so forth. Generous environment helps to make the most of a man; deficient environment may depress, inhibit, starve, and kill. To an extent unsuspected before Biology came of age, Man is modifiable by his Environment and stimulated by his Environment for better or for worse. Yet man, when he finds and uses his opportunities, is increasingly master of his environmental Fate.

Thirdly, the biological view of man sees him as a developing organism, which means more than the universal recognition of his infancy, childhood, adolescence, and so forth—a recognition obviously older than any biology, though aided by it. It means that every human organism realises a complex inheritance in a complex environment, and that every character is a resultant of two components—the hereditary nature and the environing nurture. It means that the degree of development, whether all-round or lop-sided, varies with the nurture, whether generous or niggardly. Moreover, the shape of the life-curve—the individual trajectory—is both variable and modifiable; thus childhood may be short and strained, or long and joyous; adolescence may be the successful adventure of an argosy, or a miserable shipwreck; and ageing may be, as Shakespeare said, a ripening or a rotting. The nurtural factor in development has potencies far from being fully estimated; and these affecting mind as well as body, through and through. In Whitman's unforgettable lines: "There was a child went forth every day, and what that child saw became part of him—for a day, or for a year, or for stretching cycles of years." No doubt the study of heredity confirms something of the old fatalism; yet it has to be corrected by a fuller biology which does some justice to the modifying power of nurture, and to the continual emergence of the new.

Fourthly, the biological outlook on human life implies a recognition of man as the long result of time, solidary with the rest of creation. His fabric is shot through and through with partially humanised threads from his mammalian ancestry. The past reasserts itself in his present, often inconveniently. Yet he is the outcome of a progressive evolution. It is an ascent, not a descent, that he has behind him. His flesh is heir to many ills, but there is an organic momentum within him that is stronger for integration than for the opposite. Moreover, his evolution is going on; the fountain of the new is unexhausted. The Darwinian factors, of variability and heredity, selection and isolation, continue to operate—changing and entailing, sifting and singling. The world is new every day, for better or for worse; but the trend towards betterment is normally the stronger.

Moreover, while man is biologically a scion of a mammalian stock, it is scientifically sound to recognise his apartness. For he is a

creature of rational discourse, guiding his conduct in the light of ideas, more or less conscious of his past, and more or less ready to control his future, building up a Social Heritage on a quite different plane from the Natural Inheritance which is transmitted by his much-mingled germ-plasm.

Finally, it is characteristic of the biological outlook that it sees man as an organism quivering in the web of life. Many circles of life intersect the human circle, and man's doings reverberate through Animate Nature. As Darwin continually showed, there is cumulative momentum in minutiæ, and the consequences of actions spread like ripples on the surface of a pool. No one has begun to have the biological outlook till he has begun to see man, and even each man, in his intricate web of interrelations.

In regard to the development of this biological outlook in its various aspects, which we have sought to outline, it must be clearly understood that this way of looking at things cannot be acquired by swallowing "principles of biology", or by any other short and easy method. It is the outcome of sojourning with living creatures; it is based on a multitude of carefully garnered experiences; it means hard work with masses of fact; it grows out of observation and reflection. There is no short cut to the biological outlook, though it is happily true that some vivid experience, or some teacher or fellow-student, may effect a veritable scientific conversion.

This preamble is already long, but one other introductory remark seems necessary. The biological outlook is much more than an intellectual gain; it is of incalculable practical value. Science is for Life, not life for Science; and the corollary of the biological way of looking at things is the biological control of life. Pasteur is to Darwin as works to faith. *Savoir, prévoir, pourvoir;* knowledge gives foresight, and foresight gives power. In Bacon's phrase the biological outlook is not only luminiferous, it is also fructiferous. It is not only "for the glory of the Creator", it is also "for the relief of man's estate".

The biological view of human life turns a hundred vague and perplexing puzzles into tangible flesh-and-blood difficulties that can be scientifically tackled. Man becomes more intelligible, and therefore more masterable. How many diseases have been more or less conquered; how many factors making for positive health are now being used as levers to lift the weight of "life-harming heaviness"; what success there has been in ameliorating both surroundings and work! The days of folded hands and submission are over; every year man enters, and may enter more fully, into the possession of his kingdom of enlarging life.

In regard to biological teaching in schools and colleges, it is to be feared that there is far too little Biology, in the strict sense, being taught. Insurgent Zoology no doubt, efflorescent Botany, Bio-

chemistry like a Hercules in the cradle, but what else? We see Embryology shrinking under the ægis of Anatomy; here and there a course of Biometry struggling for existence; almost like a curiosity is a course on Comparative Psychology; perhaps an extramural vindication of Comparative Physiology; Comparative Pathology hardly known, even as an idea; in a few green trees a vigorous branch of Genetics, preserved from the knife by the label Agricultural; and so we might savagely, and no doubt in some measure unjustly, continue. But where does Biology come in? We mean by Biology *the general science of organisms—the study of the nature, persistence, continuance, development, and evolution of life.*

It is a regrettable fact that there is relatively little education in Biology in the Universities of the British Empire!—There is abundance of first-class Zoology and first-class Botany, but there is relatively little General Biology. No one can seriously pretend that a little Zoology plus a little Botany makes a course of Biology. One might as well say that a whiff of oxygen and a whiff of hydrogen will serve as a drink of water. A distinguished Professor from the North was being shown round one of the greatest of the Southern Universities by a delightful and delighted student-guide. "Yes", he said, "here is Botany, which I understand; and there is Zoology, which I also understand; but what is 'Biology' which I see engraved over that portal?" The student was taken aback and stood silent; but suddenly a smile of enlightenment spread over his face, and he gave the reply: "Oh, yes, I remember now; Biology is the dogfish and the bean plant."

One reason for the paucity of biological education is that University teachers have to put too much into one short course, with the result that the more synthetic part of the programme is crowded out. No doubt it is a little difficult to teach Zoology or Botany except in the light of the great biological concepts of growth, development, correlation, variability, heredity, evolution, and so forth; yet it can be done and often is; and all science suffers for want of more of genuine Biology.

Let us take Zoology for a moment. It is so far being excellently taught, and yet there is no rapid diffusion of the biological outlook; nad the credit for what little there is must be shared with the Press and the Publishers. Doubtless there has been a sprinkling of biological information widespread throughout the community. A considerable proportion of the public may be said to know that most diseases are microbic rather than mysterious, and that the individual life begins in a fertilised egg-cell; but this fragmentary knowledge is not quite enough for the biological outlook, is it?

Our frank reproach is that the Universities, within and beyond the British Empire, fall short of their just ambition as regards Biological Education; and a large part of the reason for this is that

the hands of the teachers are too full. Keeping still to Zoology, it is plain that every year in every college should see at least *four* main courses going on. *First* there is the prolonged course, for those who are going to be teachers or investigators in Zoology. This must be comprehensive, introductory to all the various aspects of zoology, and continued for several years. *Secondly*, there must be the introductory course for Medical Students, orientated with a view to their subsequent medical studies, giving prominence to the Cell, the Germ-Cells, the Early Stages of Development, Heredity, the Principles of Morphology and Physiology, Parasites, and all that sort of thing. This is naturally to a considerable extent a biological course, but the medical orientation indicated is often conspicuous by its absence, too much general Zoology being usually insisted on. *Thirdly*, there should be a cultural course for "Arts" students, in which the main emphasis should be on ecology, the old-fashioned Natural History, in other words the study of habits and interrelations; and, of course, also on Evolution. *Fourthly*, in our judgment, there should be a short course on the Principles of Biology, with obvious, yet not stressed, applications to the problems of human life. We submit several tentative programmes of courses:

(*a*) ZOOLOGY

A Course for Medical Students

About 100 *Meetings, Lectures and Practical Work intermingled*

A.—General or Introductory Part.

1. Introductory discussion of various problems of animal life, e.g. different ways of moving, different ways of feeding, animal behaviour at various grades, animal life throughout the year, animal life in different haunts, interrelations of organisms—to bring out what organisms are, and what they busy themselves with, and how animals differ from plants.

2. A bird's-eye view of the Animal Kingdom. The basis of classification. What is meant by species and varieties. The great lines of animal evolution, e.g. Vertebrate, Arthropod, Annelid.

3. Several illustrations of Protozoa, e.g. Amœba, Paramœcium, Malaria-organism, Sleeping-sickness organism. Other disease-causing Protozoa and their vehicles. Detailed description of the Animal Cell and Cell-division.

4. A number of Invertebrate types selected to illustrate particular points, e.g. the beginnings and evolution of tissues; the division of labour in the body and the establishment of organs; the evolution of the nervous system and the succession of steps in a reflex action; the various ways of solving the same problem, e.g. respiration.

5. Introductory study of early stages of development, e.g. in sea-

urchin. The egg-cells and sperm-cells. Maturation, fertilisation, and segmentation. The significance of larvæ. Comparison of a number of life-histories, e.g. jellyfish, earthworm, crab, butterfly, sea-urchin, and pond-snail. Alternation of generations.

6. A number of Vertebrate types selected to illustrate particular points, e.g. homologies, based on a thorough comparison of such skeletons as those of birds and mammals; the differentiation of the food-canal and its outgrowths; the everyday functions of the body: the regulatory system and the evolution of the ductless glands; different modes of reproduction, leading up to mammalian viviparity. The evolution of sense-organs and brain.

7. The fact of evolution. The evolving organisms and the evolving system of interrelations. Illustrations from the past and the present.

B.—Special Part.

8. The Study of important parasites and their life-histories, e.g. Trematodes, Tapeworms, and Nematodes, with particular emphasis on forms like the species of Bilharzia and Hookworm. Insects and Acarines as carriers as well as parasites. Return to Protozoon parasites. Illustrations of the Web of Life and man's share in it.

9. History of the germ-cells. The principles of Genetics. Mendelian Inheritance. Reversions. The concept of Unit-Characters. Heredity and disease. Hormones and Heredity.

10. Experimental Embryology. Influence of Nurture on the development of hereditary nature, modern experiments bearing on this. Influence of changes in habits and surroundings; how far of racial significance. Question of the transmission of "acquired characters" or somatic modifications.

11. Brief comparative study of sex and reproduction. Sex dimorphism at various levels in the animal kingdom. Gonadial or sex hormones. Darwin's theory of sex-selection and its modern form.

12. The factors in evolution brought togther. Fluctuations and Mutations, Selection, and Isolation.

The practical work of three kinds: (*a*) Manipulative exercises in dissection and microscopic technique; (*b*) as a discipline in precision—a very thorough study of particular things, e.g. dog's skull, bird's skeleton, brain of skate, eye of ox, appendages of crustacean and insect; and (*c*) direct illustrations of what has been discussed in the lectures.

(*b*) INTRODUCTORY ZOOLOGY

A Course for Arts and Science Students

About 100 *Hours, of which* 50 *are devoted to Practical Work*

1. General Survey of the Animal Kingdom. The characteristics of the great classes. Structure, function, habits, life-histories, and interrelations of a series of types and groups, e.g. Amœba, Paramœcium, Sponge, Hydra and the Hydroids, Medusæ, Sea-Anemones and Corals,

Unsegmented Worms, Earthworm and other Annelids, Starfish and Sea-Urchin, Crayfish and other Crustaceans, Peripatus, Centipedes, Millipedes, Insects, Spiders and other Arachnids, Snails and other Molluscs, Primitive Vertebrates, Skate and other Fishes, Frog and other Amphibians, Reptiles, Birds, and Mammals. Special studies of selected indigenous animals.

2. The Problems which the Animal has to solve: Nutrition, Movement, Self-preservation, Race-continuance, etc. Illustrations of the variety of solutions. The everyday functions of the body—contractility, irritability, digestion, circulation, respiration, excretion, integration—Introduction to comparative physiology. The study of Animal Behaviour.

3. Introduction to the study of structure. The form of the body; the organs; the tissues; the cells and their protoplasm. Some general ideas of morphology illustrated, e.g. homology, differentiation, substitution of organs.

4. Introduction to the study of development. Early chapters in development, e.g. of Sea-Urchin and Nematode. Types of embryos and larvæ. The recapitulation doctrine. Introduction to the study of heredity.

5. Interrelations of animals with one another and with plants. Commensalism, symbiosis, other partnerships, social animals.

6. The Haunts of Life and how animals are adapted to their peculiarities: littoral, pelagic, abyssal, freshwater, terrestrial, aërial. The peopling of land and sea. Introduction to the study of the Past (palæontology). The factors in Evolution illustrated.

7. The Biology of the Seasons. The life of animals considered in relation to external periodicities.

PRACTICAL WORK: The macroscopic and microscopic study of a series of types.

(c) A SHORT NATURAL HISTORY COURSE FOR GENERAL STUDENTS

Forty Meetings in all, with Demonstrations

A. A General Survey of the Animal Kingdom.
B. The problems that animals have to solve, such as nutrition, movement, self-preservation, and race continuance. The everyday functions of the body and the various forms of animal behaviour.
C. The General Structure of a higher animal and the adaptation of its parts for special uses.
D. Different kinds of Life-Histories; introduction to the study of Heredity.
E. Interrelations of animals with one another and with plants.
F. The life of animals throughout the year.
G. The Haunts of Life; the Peopling of Land and Sea; the Evolution of Animals.

(*d*) A SHORT COURSE ON THE PRINCIPLES OF BIOLOGY

About Forty Meetings devoted to the Study of Biology with Relevant Practical Work

1. The Distinctiveness of "Organisms", or the Criteria of Livingness.
2. "Function" and "Behaviour", or the everyday life of the Organism.
3. The System of Animate Nature.
4. The Individual and the Race.
5. Originative Factors in Evolution; Variation, etc.
6. Directive Factors in Evolution; Selection, etc.

THE STUDY OF LIVING ORGANISMS

At a recent congress of University teachers met in London to discuss the teaching of Biology in the Universities, there was only a single reference to Eugenics! While we are personally convinced that in schools the *indirect* method of instruction in regard to the biology of human life has most to recommend it, leaving the outlook to develop in each mind, we are also convinced that the continuance of such detached aloofness in biological education in the Colleges and Universities is not only unprogressive, but unscientific.

We wish to plead for a form of biological discipline which has never been tried as much as it deserves—the study of living animals. In many Universities and Colleges it is part of the routine that students should study living Amœbæ, various animalcules, Hydra, and so forth; but the study of the living soon comes to an end. In all marine laboratories the student has, however, opportunities of extending this study of the living in very delightful ways, and no one can forget the revelation afforded by the first watching of, say, a vigorous starfish. Our plea is for an extension of this kind of study, for it is rewarding and promiseful. For small groups of students it is sometimes realisable by means of excursions.

In a well-known educational institution for the Training of Teachers, there is no dissection at all, unless a student particularly wishes it in order to solve some problem. Yet the teaching and learning of Zoology in this institution reach an unusually high level. Its main practice is worth following, to the extent of having much study of the living creature. For this study gives impressions that dissection can never give; it illumines the concepts of growth, development, struggle, variation, and so on; it evokes *the biological outlook.*

To watch a transparent egg developing, to follow the life-history of a dragonfly or a tadpole, to watch an ant-lion in its ways, to scrutinise a beehive or a formicarium, to measure and plot out the rapid growth of a caterpillar in size and weight, to study day after

day the progressive behaviour of a starfish in learning to right itself when turned upside down, to keep the hermit-crab's diary for him, to discover the succession of populations in a jar of pond water, to make a careful record of the differences between the members of a large family, say of chickens, and so on as opportunities arise —*that* is the line best of all worth following. Our proposition is: the biological outlook arises more from the study of the living than from the well-established and admittedly indispensable analytic studies which need no defence.

Everyone who has tried knows that the study of living animals is peculiarly difficult; and many creatures have an exasperating way of dying just when we particularly wish them to be alive. For a large class the study of living animals above microscopic dimensions may seem almost utopian. Yet it can be done; and it is well worth while.

It must not be supposed for a moment that we are proposing all this as a *substitute* for dissection and other analytic methods, which have their own values and rewards. We are simply pleading for a fairer trial of a fundamental discipline, as rewarding as it is obvious.

Nor let anyone suppose that the study of a life-history, or of an animal's everyday behaviour, or of its relations with its environment, animate and inanimate, need fail to be brain-stretching. Resolutely pursued, the study of the living animal will prove a sound discipline for the scientific mood. It often implies some education in ingenuity, too; for it is rarely easy to study living creatures intimately, yet without doing them any hurt.

Our plea may be received more sympathetically when it is remembered that in India, so large and clamant a part of the Empire, there is a widespread repulsion to our predominantly necrological methods; and our own students often feel the same, women specially, and poets too. Now when the taking of life is abhorrent, and the handling of the dead animal is repugnant, surely, in the name of education, the natural and promiseful way out is to get the teachers in Indian Universities, Colleges, and Schools to think out a carefully-planned study of *living animals*, such that it will illustrate biological principles, and engender the biological way of looking at life. Moreover, it is common sense that the result of instruction depends in part on the degree in which those concerned teach and learn *gladly*. That the glad way of teaching and learning biological science in India is through the study of the living organism, we are convinced; and more of this will do us good nearer home.

Here, then, let our volumes end as they began; and as their chapters and sections have been conceived and treated throughout; in short, with the Science of Life, as Living.

VIVENDO DISCIMUS.

APPENDIX IV

GUIDE TO BIOLOGICAL READING

THIS is merely a *representative* selection of useful books, but many of the larger treatises on our list, e.g. Hartmann's, have good Bibliographies. Some of the simpler books are marked with an asterisk.

INTRODUCTIONS

The idea of beginning a new study with a Primer or short Introduction is natural, but it is not always very effective. It takes a genius to write a worthy introduction to a science; some are too elementary, and others are too like pemmican. Their restricted size precludes the use of picturesque details on which the mind of a beginner naturally fastens. It is usually better to begin more indirectly, with the biography of some great biologist, or with a naturalist's travels, or with out-of-door sketches—comparable to taking a walk in the country with a friendly biologist.

SOME SMALL INTRODUCTORY BOOKS

*F. W. GAMBLE, The Animal World. Home University Library.
R. LULHAM, Introduction to Zoology. 1913.
J. G. NEEDHAM, General Biology. Ithaca, 1910.
T. JEFFERY PARKER, Elementary Biology. 1891.

INDIRECT INTRODUCTIONS

C. F. HODGE, Nature-Study and Life. Boston, 1902.
JULIAN S. HUXLEY, Essays of a Biologist. 1923.
Essays in Popular Science. 1926.
O. LATTER, Natural History of Common Animals. Cambridge, 1904.
M. I. NEWBIGIN, Life by the Seashore.
*PATRICK GEDDES, Chapters in Modern Botany.
*W. J. P. BURTON, Some Secrets of Nature: Short Studies in Field and Wood. 1913.
J. ARTHUR THOMSON, Editor, Outline of Science. 3 vols. 1922.
WELLS, HUXLEY, and WELLS, The Science of Life. 1929.

INTRODUCTIONS CENTRED IN ONE ANIMAL OR PLANT

*T. H. HUXLEY, The Crayfish, an Introduction to the Study of Zoology. 1880. Unsurpassed.
W. H. FLOWER, The Horse. 1891.
A. MILNES MARSHAL, The Frog. 11th edition by F. W. Gamble. 1914.
ST. GEORGE MIVART, The Frog. 1874.
*MARSHALL WARD, The Oak Tree.
E. E. AUSTEN, The House-Fly.

F. E. CHESHIRE, Bees and Bee-Keeping.
T. W. COWAN, The Honey-Bee.
C. DARWIN, Formation of Vegetable Mould through the Action of Worms. 1881.
Insectivorous Plants.
*MACGREGOR SKENE, Common Plants.
COWARD, British Birds. 3 vols. Very useful, beautifully illustrated.
H. ST. J. K. DONNISTHORPE, British Ants.
F. LAING, The Cockroach.
A. S. LESLIE and SIR A. E. SHIPLEY, The Grouse in Health and in Disease.

BIOLOGY STUDIED IN RELATION TO PARTICULAR CLASSES

F. E. BEDDARD, Earthworms. Cambridge Manuals.
C. W. BEEBE, The Bird.
G. N. CALKINS, The Protozoa.
W. T. CALMAN, Life of Crustacea.
G. H. CARPENTER, Biology of Insects.
R. L. DITMARS, Reptiles of the World.
J. W. FOLSOM, Entomology.
S. J. HICKSON, Introduction to the Study of Corals.
F. B. KIRKMAN and others, British Bird Book. 4 vols.
H. M. KYLE, Biology of Fishes.
J. G. MILLAIS, Mammals of Great Britain and Ireland. 3 vols.
*FRANCES PITT, Waterside Creatures; Wild Creatures of Garden and Hedgerow; Woodland Creatures. Most admirable ecology.
C. TATE REGAN, Freshwater Fishes of the British Isles.
TH. SAVORY, Biology of Spiders.
*MACGREGOR SKENE, Common Plants. 1921.
*J. J. SIMPSON, Chats on British Mammals; More Chats on British Mammals; Romance of Natural History. Very effective books.
R. SOUTH, Butterflies of the British Isles; also Moths of the British Isles.
*A. L. THOMSON, Birds. Home Univ. Library. A very suggestive introduction.
J. ARTHUR THOMSON, Biology of Birds.
C. VON WYSS, Living Creatures. Admirable.
C. WARBURTON, Spiders. Cambridge Manuals.
B. B. WOODWARD, Life of Molluscs.
M. HERING, Biologie der Schmetterlinge. 1926. An excellent treatise on Lepidoptera.
H. ELTRINGHAM, Butterfly Lore. Oxford, 1922.
G. E. H. BARRETT-HAMILTON and others, History of British Mammals.
R. LYDEKKER, British Mammals.
H. S. JENNINGS, The Biological Basis of Human Nature. 1930. Very valuable.
ARTHUR WILLEY, Amphioxus and the Origin of the Vertebrates.
Various Authors, Monographs on Marine Animals, e.g. Sea-urchin, Limpet, Alcyonium, Hermit-crab. Issued by Liverpool Marine Biol. Committee, Liverpool University.

SOME BIOGRAPHIES AND HISTORIES AS USEFUL INTRODUCTIONS

*W. A. Locy, Biology and its Makers. New York, 1908.
L. C. Miall, Early Naturalists.
F. Darwin, The Life and Letters of Charles Darwin.
*Chalmers Mitchell, Life of Huxley.
L. Huxley, The Life and Letters of Thomas Huxley.
Edward Clodd, Life of Huxley.
*R. V. Radot, Life of Pasteur.
Alfred Russel Wallace, My Life.
Herbert Spencer, Life and Letters.
F. Galton, Memories of my Life, 1908.

SOME NATURALIST TRAVELS AS INTRODUCTIONS TO BIOLOGY

A. Alcock, Naturalist in the Indian Seas.
*W. Beebe, The *Arcturus* Adventure.
World's End Zoology (Galapagos Islands).
*A. E. Brehm, From North Pole to Equator. 1896.
A. R. Wallace, Island Life. 1880.
*W. H. Hudson, Naturalist in La Plata. 1892.

INTRODUCTORY SKETCHES

*Margaret Thomson, Threads in the Web of Life. 1910. For young people.
*J. Arthur Thomson, Biology of the Seasons. 1911.
*J. Arthur Thomson, The Wonder of Life. 1914.
*Gilbert White, Natural History of Selborne. 1788.

LESS ELEMENTARY INTRODUCTIONS

*Geddes and Thomson, Biology. Home University Library.
*J. Arthur Thomson, The Study of Animal Life. 4th edition. 1917.
*J. B. S. Haldane and J. S. Huxley, Animal Biology. Oxford, 1927.
G. N. Calkins, Biology. New York, 1914.
P. Chalmers Mitchell and G. P. Mudge, Outlines of Biology. 3rd edition. 1911.
C. Lloyd Morgan, Animal Biology.
Hilzheimer and Haempel, Handbuch der Biologie der Wirbeltiere. 2 vols. Stuttgart, 1912.
Nusbaum, Karsten, and Weber, Lehrbuch der Biologie. Leipzig, 1911. A book of great excellence.
W. J. Dakin, Introduction to Biology.
*Sir Arthur E. Shipley, Life.
L. L. Burlingame, General Biology.
*F. E. Weiss, Plant Life and its Romance.
Sir F. W. Keeble, Life of Plants.
W. F. Dakin, General Zoology.

REPRESENTATIVE CLASSICS

HERBERT SPENCER, Principles of Biology. 2 vols. 1864–1866; revised edition 1908.
CHARLES DARWIN, The Origin of Species, 1859.
ALFRED RUSSEL WALLACE, Darwinism. 1889.
ERNST HAECKEL, Generelle Morphologie. 1866.

GENERAL BOOKS ON BIOLOGY

A. HARTMANN, Allgemeine Biologie. Jena. The best recent treatise on general biology. Jena, 1927. With fine Bibliography.
*S. J. HOLMES, General Biology. 1930.
J. S. HUXLEY and J. B. S. HALDANE, Animal Biology. 1928. A very educative, up-to-date book.
O. HERTWIG, Allgemeine Biologie. 7th edition. Jena, 1923.
J. G. NEEDHAM, General Biology.
F. W. NEGER, Biologie der Pflanzen. 1913.
E. S. RUSSELL, The Interpretation of Development and Heredity. A Study in Biological Method. Oxford, 1930. A very important treatise.
A. F. SHULL, Principles of Animal Biology.
G. N. CALKINS, Biology. New York, 1914.
*A. DENDY, Evolutionary Biology. Revised edition. 1923.
*J. ARTHUR THOMSON, Everyday Biology. 1924.
The New Natural History. 3 vols. 1926. Much general biology and ecology.
*L. L. WOODRUFF, Foundations of Biology.
SIR ARTHUR KEITH, The Engines of the Human Body. 1925.
L. A. BORRADAILE, The Animal and its Environment.
*F. W. FLATTELY and C. L. WALTON, Biology of the Seashore.
FRISCH, GOLDSCHMIDT, and WINTERSTEIN (Editors), Ergebnisse der Biologie. 1926. 5 vols. Very valuable.

PROBLEMS OF GENERAL BIOLOGY

H. BERGSON, Creative Evolution. 1911.
*F. O. BOWER, Botany of the Living Plant. 1919.
HANS DRIESCH, The Science and Philosophy of the Organism. 1908.
*F. W. GAMBLE, Animal Life. 1908.
J. JOLY, The Abundance of Life. Proceedings Royal Dublin Society, vii, 1891, pp. 55–90; reprinted in The Birthtime of the World. 1915. An important essay.
JAMES JOHNSTONE, The Philosophy of Biology. Cambridge, 1914.
HENRY FAIRFIELD OSBORN, The Origin and Evolution of Life. 1918.
E. S. RUSSELL, The Study of Living Things. 1924.
*ARTHUR E. SHIPLEY, Life. Cambridge, 1923.
*J. ARTHUR THOMSON, The Wonder of Life. London, 1914.
J. VON UEXKÜLL, Theoretical Biology. 1926.
*GEDDES and THOMSON, Biology. Home Univ. Library.

GENERAL BOOKS ON ZOOLOGY

Parker and Haswell, Textbook of Zoology. 2 vols.
A. Sedgwick, Student's Textbook of Zoology. 3 vols.
Sir E. Ray Lankester, Treatise on Zoology. 5 vols.
*J. Arthur Thomson, Outlines of Zoology. 8th edition. 1929.
G. C. Bourne, An Introduction to the Study of the Comparative Anatomy of Animals.
W. J. Dakin, Elements of General Zoology.
J. Graham Kerr, Zoology.
Shipley and Harmer (Editors), The Cambridge Natural History. 10 vols. Invaluable.
*O. Latter, Natural History of Common Animals. An excellent guide.
*R. Lulham, Introduction to Zoology. An excellent open-air book of great thoroughness.
W. Hatchett Jackson, Re-ed. of Rolleston's Forms of Animal Life.
Yves Delage and others, Traité de Zoologie Concrète. 6 vols.

BOTANICAL

*Coulter, Barnes, and Cowles, Textbook of Botany. 2 vols. 1911. With useful Bibliography.
W. F. Ganong, The Living Plant: a description and interpretation of its functions and structure. 1913.
*E. Strasburger, Textbook of Botany. 1919.
W. J. V. Osterhout, Experiments with Plants. 1905.
P. Sorauer, A Popular Treatise on the Physiology of Plants. 1895.
Sir John Lubbock, Flowers, Fruits and Leaves. 1908.
Marcel E. Hardy, The Geography of Plants. Cambridge, 1920.
*Macgregor Skene, Biology of Flowering Plants. An excellent treatise.
A. G. Tansley, Elements of Plant Biology.
W. N. Jones and M. C. Rayner, Plant Biology.
*J. Small, What Botany Really Means. 1928.

ECOLOGICAL, MOSTLY "NATURAL HISTORY"

*Gilbert White, Natural History of Selborne. 1788.
C. Elton, Animal Ecology. 1927.
*Coulter, Barnes, and Cowles, A Textbook of Botany. Vol. II. Ecology. 1911. With good Bibliography.
Pearse, Textbook of Ecology. 1926.
Kerner, Natural History of Plants. 2 vols. 1890.
Tansley, Plant Ecology.
Karl Semper, The Natural Conditions of Existence as they Affect Animal Life. 1881.
*P. Geddes, Chapters in Modern Botany.
*L. Borradaile, The Animal and its Environment. 1923.
C. C. Adams, Guide to the Study of Animal Ecology. New York. 1913.
W. M. Wheeler, Social Insects.

CHARLES DARWIN, The Formation of Vegetable Mould through the Action of Worms. 1881.

K. GROOS, The Play of Animals. 1900.

HESSE and DOFLEIN, Tierbau und Tierleben. 2 vols. Leipzig and Berlin, 1910, 1914. Doflein's volume on Tierleben is a treasury of modern ecology.

WARMING, Ecology of Plants. Oxford, 1909. Very valuable.

HILZHEIMER and HAEMPEL, Handbuch der Biologie der Wirbeltiere. 2 vols. Stuttgart, 1912, 1913. An excellent book dealing mainly with the ecology of Vertebrates.

H. E. HOWARD, Territory in Bird Life.
  Bird Behaviour. Of great importance.

SIR JOHN LUBBOCK (LORD AVEBURY), Ants, Bees, and Wasps. Internat. Sci. Series.

P. A. BUXTON, Animal Life in Deserts.

A. G. TANSLEY, Practical Plant Ecology.

L. J. HENDERSON, Fitness of the Environment.

R. LYDEKKER, J. T. CUNNINGHAM, G. A. BOULENGER, and J. ARTHUR THOMSON, Reptiles, Amphibians, Fishes, and Lower Chordates 1912. Continuing Pycraft's Birds. Largely ecological.

E. W. SWANTON, British Plant Galls.

J. G. NEEDHAM and J. T. LLOYD. Life of Inland Waters.

NUSBAUM, KARSTEN, and WEBER, Lehrbuch der Biologie. Leipzig, 1911. An excellent treatise on ecology.

*FRANCES PITT, Wild Creatures of Garden and Hedgerow. Other admirable books.

W. P. PYCRAFT, History of Birds. 1910. A masterly book, rich in ecological material and suggestion.

SHELFORD, Animal Communities. Chicago, 1914.

*J. ARTHUR THOMSON, The Wonder of Life. 1914.

*MARGARET THOMSON, Threads in the Web of Life. 1910. For young people.

C. W. TOWNSEND, Sand Dunes and Salt Marshes. 1913.

*TREGARTHEN, Life of Badger; Life of Otter; Life of Fox, etc. Excellent studies in ecology.

W. M. WHEELER, Ants. Columbia Univ. Series.

*GILBERT WHITE, Natural History of Selborne. 1788. An evergreen initiation.

INTERRELATIONS OF FLOWERS AND INSECTS

CHARLES DARWIN, Fertilisation of Orchids. 1862.
  Cross-Fertilisation. 1876.
  *Insectivorous Plants.

HERMANN MÜLLER, Fertilisation of Flowers by Insects. 1883.

*PATRICK GEDDES, Chapters in Modern Botany. 1893.

KERNER, Flowers and their Unbidden Guests.
  Natural History of Plants. 2 vols.

LUBBOCK, British Wild Flowers in Relation to Insects. 1875.

OTHER INTERRELATIONS

*CHARLES DARWIN, The Formation of Vegetable Mould through the Action of Worms. 1881. An ecological classic.

S. GAYE, The Great World's Farm. London, 1893.

WIESNER, Biologie der Pflanzen. Wien, 1889. A terse survey of the ecology of plants.

E. A. ORMEROD, Injurious Insects. 2nd edition. 1891.

GOEBEL, Pflanzen-biologische Schilderungen. Marburg, 1889.

SCHIMPER, Wechselbeziehungen zwischen Pflanzen und Schnecken. Jena, 1883. Plants and Snails.

BUSGEN, Honig-tau. Honey-Dew and Aphids.

O. HERTWIG, Die Symbiose. Jena, 1883. Green Algæ in various animals.

*F. KEEBLE, Plant-Animals. Cambridge, 1910.

BUCHNER, Tier und Pflanze im intracellulare Symbiose.

P. J. VAN BENEDEN, Animal Parasites and Messmates. Internat. Sci. Series. 1876.

FANTHAM, STEPHENS, and THEOBALD, Animal Parasites of Man.

E. T. CONNOLD, British Oak-Galls. 1908.

L. LALOY, Parasitisme et Mutualisme dans la Nature. Paris, 1906.

R. LEUCKART, Parasites of Man. Edinburgh, 1886.

NEGER, Biologie der Pflanzen. A very important treatise on the Ecology of Plants.

*MACGREGOR SKENE, Common Plants. A delightful introduction to the Ecology of Plants.

The Biology of Flowering Plants.

Parasitic Plants. In Thomson's Ways of Living. 1926.

J. RENNIE, Parasitic Animals. In Thomson's Ways of Living. 1926.

*A. E. SHIPLEY, Minor Horrors of War. 2 vols. 1915 and 1916.

SEASONAL NATURAL HISTORY

*J. ARTHUR THOMSON, Biology of the Seasons. 1911.

*L. C. MIALL, Round the Year. 1896.

K. RUSS, Das heimische Naturleben im Kreislauf des Jahres. Berlin, 1889.

EDWARD THOMAS and others, British Country Life in Spring and Summer. 1907.

British Country Life in Autumn and Winter. 1907.

J. ARTHUR THOMSON, Nature Round the Year. For young people.

(Editor) Ways of Living. 1926.

*GILBERT WHITE, Natural History of Selborne. 1788.

SOCIAL ANIMALS

*FR. ALVERDES, Social Life in the Animal World. 1927. Sketch of Animal Sociology.

W. M. WHEELER, Social Life among the Insects, 1923.

A. ESPINAS, Les Sociétés Animales. Paris, 1877. A pioneering book.

P. GIROD, Les Sociétés chez les Animaux. Paris, 1890.

P. Kropotkin, Mutual Aid, a Factor in Evolution. 1902.
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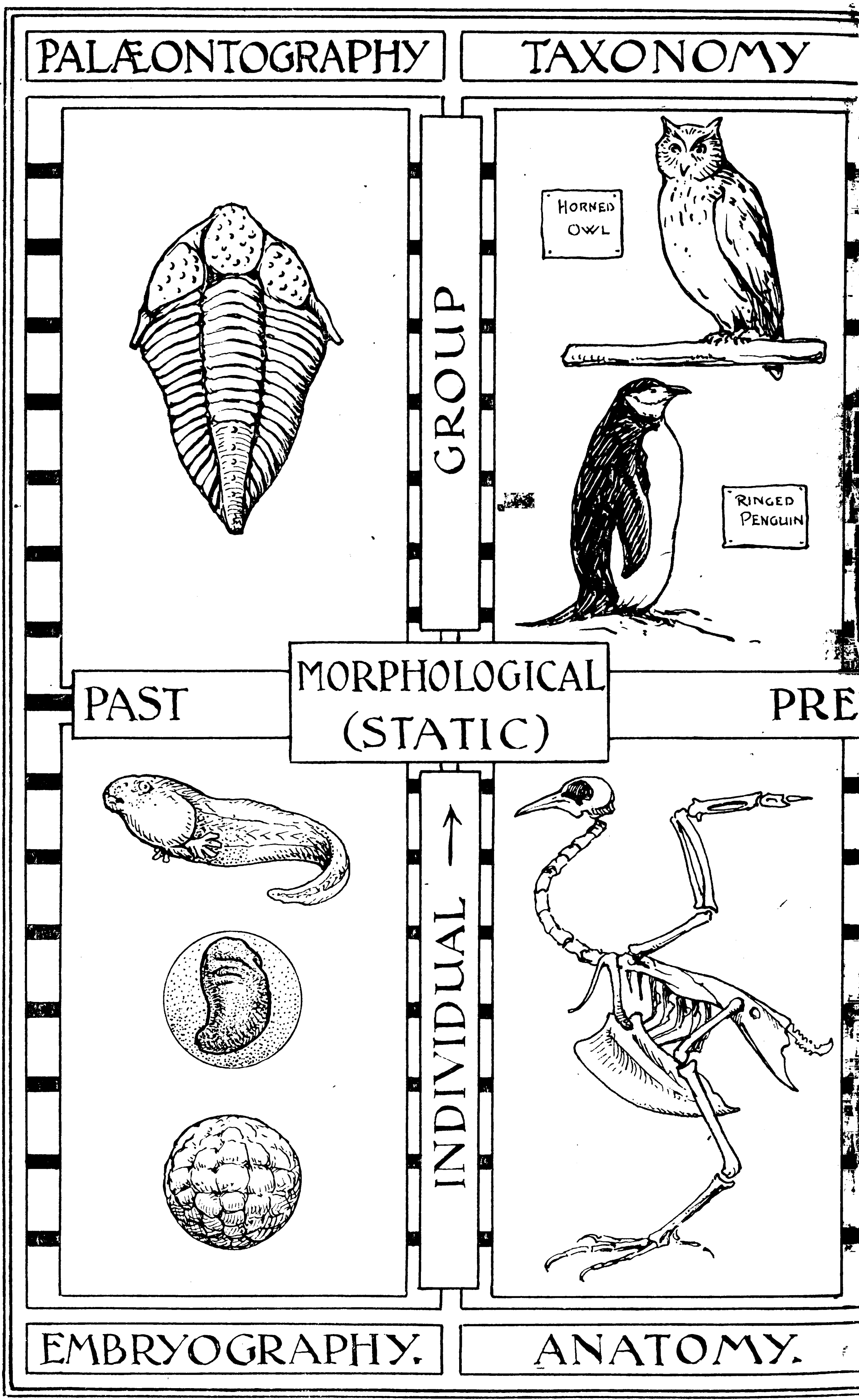

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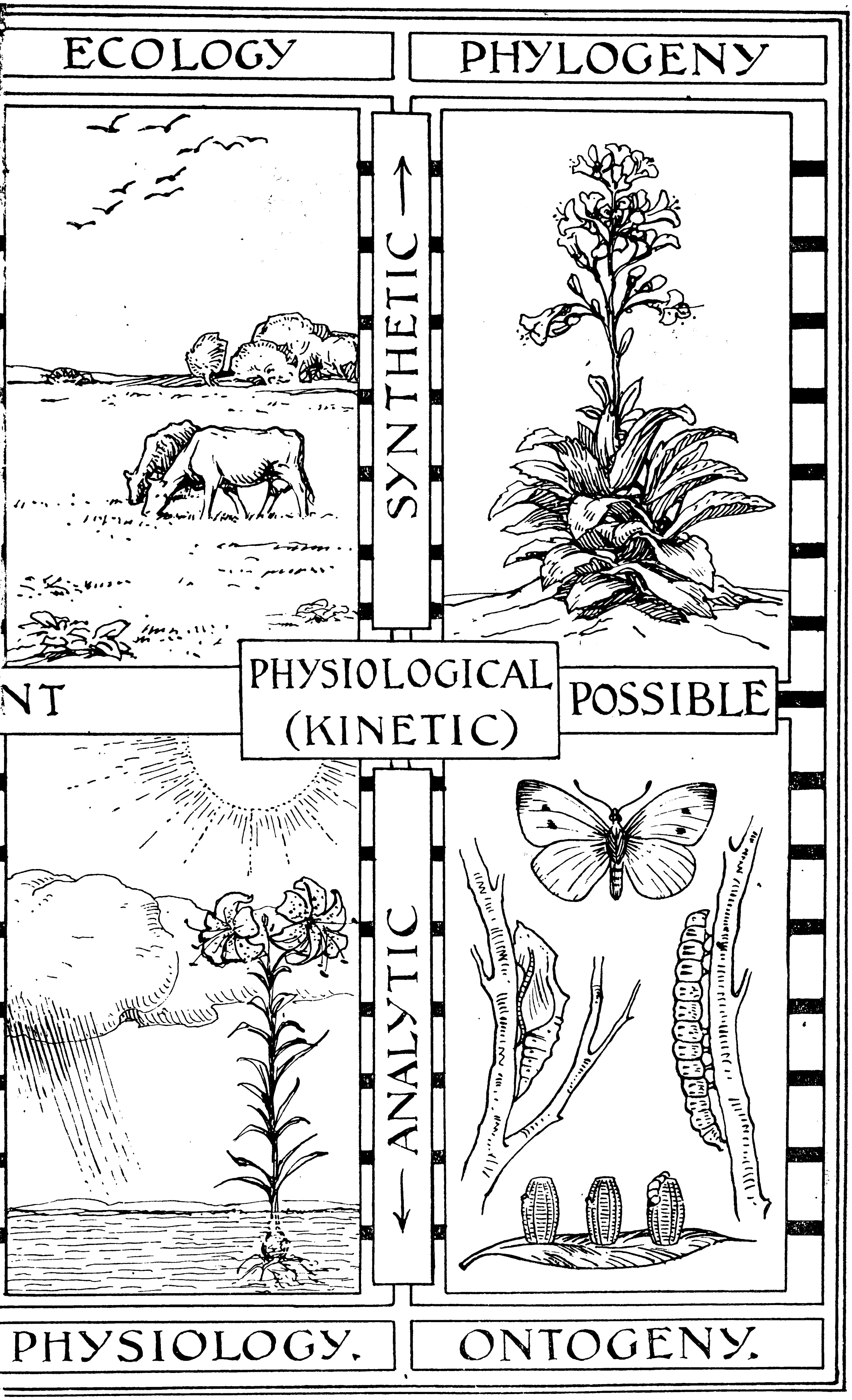
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OUTLINES OF GENERAL BIOLOGY

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AND

PATRICK GEDDES

VOLUME TWO